MORRISON'S

PRACTICAL ENGINEER

AND

MECHANICS' GUIDE,

CONTAINING

A GLANCE AT THE EARLY HISTORY OF STEAM; ITS APPLICATION TO PUMPING; ITS LATER USE FOR RAILROADS AND STEAMBOATS; ITS MORE EXTENSIVE USE FOR GENERAL MACHINERY.

THE SETTING AND MANAGEMENT OF BOILERS:

THE MODERN STEAM ENGINE; HOW IT SHOULD BE MANAGED. DESCRIPTION AND APPLICATION OF THE INDICATOR. ILLUSTRATIONS SHOWING THE ADVANTAGE OF THE ENGINE BEING IN THE BEST POSSIBLE CONDITION FOR DUTY.

SPECIAL INFORMATION FOR ENGINEERS AND FIREMEN.
QUESTIONS AND ANSWERS.

TABLES AND RULES

FOR DEMONSTRATING THE ACTUAL WORKING OF THE ENGINE, WITH METHODS OF CORRECTING THE DEFECTS. RULES FOR CALCULATIONS. TABLES FOR VARIOUS CALCULATIONS RELATING TO METALS AND OTHER MATERIALS. TESTS AND METHODS OF WORKING METALS. USEFUL PRACTICAL INFORMATION, RECEIPTS, ETC.

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PREFACE.

In offering the third edition of this book to the Public, especially to that class known as Steam Engineers, the author desires to lay before them such facts and general information as he has gained by an experience of many years in the business. In doing this he wishes to help to elevate, and make more competent a large class, which in this age of Steam, has become an important element in the world's advancement, and upon which largely depends the safety of transportation of passengers and freight throughout the world. Also, in the busy hives of industry everywhere, much depends upon the economical production, care, and useful application of *Steam*.

In presenting this book, it is not claimed that the rules, tables and formulas for calculation are entirely new, the author is largely indebted to such works as Haswell, Winslow, Briggs, Bacon and Williams, for which he makes due acknowledgement.

But seeing from many years intercourse with the class of men herein named, the great need of a practical treatise on Steam Engineering, presented in such a form as would be readily understood by those directly interested, and especially beneficial to young engineers, he cannot but hope this work will reach the class for whom it is intended, and be found interesting and helpful to them.

Slight changes have been made in a few instances, and the page on electric lighting has been re-written, to meet the greatly reduced cost of electric lighting machinery, materials, and supplies. About twenty new pages have been added, and some which did not seem as useful have been omitted. The book, as improved, is submitted to the public with thanks by the author for their appreciation of the former editions.

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DEFINITIONS

OF THE SIGNS USED IN THE FOLLOWING WORK.

$=$ *Equal to.* The sign of equality; as 16 oz.$=$1 lb.

$+$ *Plus*, or *More.* The sign of addition; as $8+12=20$.

$-$ *Minus*, or *Less.* The sign of subtraction; as $12-8=4$.

$\times$ *Multiplied by.* The sign of multiplication; as $12\times8=96$.

$\div$ *Divided by.* The sign of division; as $12\div4=3$.

$\backsim$ *Difference between the given numbers or quantities;* thus, $12\backsim8$, or $8\backsim12$, shows that the less number is to be subtracted from the greater, and the difference, or remainder, only, is to be used, so, too, *height$\backsim$breadth* shows that the difference between the height and breadth is to be taken.

$: \; :: \; :$ *Proportion*; as $2 : 4 :: 3 : 6$; that is, as 2 *is to* 4, *so is* 3 *to* 6.

$\sqrt{}$ *Sign of the square root;* prefixed to any number indicates that the square root of that number is to be taken, or employed; as $\sqrt{64}=8$.

$\sqrt[3]{}$ *Sign of the cube root;* and indicates that the cube root of the number to which it is prefixed is to be employed, instead of the number itself; as $\sqrt[3]{64}=4$.

^{2} *To be squared, or the square of;* shows that the square of the number to which it is affixed is the quantity to be employed; as $12^2\div6=24$; that is, that the square of 12, or $144\div6=24$.

^{3} Indicates that the cube of the number to which it is subjoined is to be used ; as $4^3=64$.

. *Decimal point*, or *separatrix.*

$\overline{}$ *Vinculum.* Signifies that the two or more sums, over which it is drawn, are to be taken together, or collectively, as forming one sum, thus, $\overline{4+6}\times4=40$; whereas, without the vinculum, $4+6\times4=28$; also $12-\overline{2\times3+4}=2$; and $\sqrt{\overline{5^2-3^2}}=4$. So, also, $\sqrt{(5^2-3^2)}=4$.

% *Sign of per cent.* Signifies so much per cent; as \$1.00 at 6%, or 6% of \$1.00=6 cents.

$^\circ \; ' \; ''$ Signifies degrees, minutes and seconds.

A GLANCE AT THE HISTORY OF STEAM.

Steam has been used as a motive power for upwards of two hundred years, but not until James Watt, near the latter part of the last century, made a successful application of it for driving machinery and pumping water, and later Robert Fulton and Oliver Evans applied it to the steamboat, and George Stephenson to the locomotive, was it considered a success. Although the early efforts of Watt were very crude, yet his principles of the steam engine are the base of the advanced successful steam engine of to-day. The same ideas of expansion, condensation and regulation by automatic cut-off, occupied his thoughts (although he did not make a success of the last), and were the controlling principle in all his plans and efforts.

From the cumbersome mass of the single acting steam cylinder, the ponderous beam and counter balance weight, and later the enormous fly wheel, have come the beautiful, symmetrical, compact, strong mechanism composing the structure of the engine of to-day; and instead of a machine requiring the consumption of 10 lbs. or more coal per hour, to produce one horse power, we have the modern high speed, high pressure, compound, condensing, jacketed cylinder, automatic cut-off engine, capable of running with best form of boilers, with $1\frac{1}{4}$ lbs. of coal per horse power, per hour.

THE SETTING AND CARE OF BOILERS.

As so much depends on the structure, setting and care of boilers, to produce favorable results, special attention is given to those points.

BOILERS.

The horse power of the boilers should be 20 per cent. greater than the maximum power of the engine, and when steam is used for heating and other purposes, a liberal allowance should be made. With the indicator we may determine very closely the performance of the engine; with the boiler it is very uncertain and vague what may be going on in the furnace, and inside the shell we cannot so easily determine. The engineer must depend largely upon his judgment. Close observation may, however, teach much. The Horizontal Return Tubular boiler as the kind most generally used, is referred to here. The mistake is frequently made of crowding the grate up too close to the shell. A vessel of water when held close to the flame of a lamp, will speedily be covered with smoke, and take a longer time to boil than if kept clear of the flame. Therefore, a plenty of room should be allowed for the complete combustion of the products of the fuel, and to prevent a deposit of unconsumed carbon on the relatively cooler surfaces of the boiler. The grates, therefore, should not be less than 25 inches to 30 inches below the shell. If the boiler front will not admit of it they may be pitched back somewhat, but not to exceed $1\frac{1}{2}$ inches to the foot. Have grates of such construction as will give abundant air space.

The width of the furnace inside should be at least 6 inches more than the diameter of the boiler, and of sufficient depth to allow ½ of one square foot of grate surface to each horse power of the boiler. The bridge wall should not be over 12 inches high, and for one-half the distance between the bridge wall and back end, carry a flat incline to within 10 inches of the shell of the boiler and thence run horizontal to the back. Do not attempt to conform to the curve of the boiler.

It is a disadvantage to return the smoke and gases after passing the tubes over the top of the boiler. The temperature of the steam inside of the boiler at 80 lbs. pressure is about 320°. Any reduction of the gases below that temperature, would actually cool the boiler. Not infrequently the temperature in the flue after leaving the tubes, may be less than 300° Fahrenheit, which would act as a wet blanket upon the boiler, and would result in loss. Any apparatus placed in the flue for the purpose of utilizing the heat. in heating feed water, must result in loss, unless the flue is unnecessarily large. A boiler correctly proportioned should exhaust the heat from its gases down to about 400° temperature by the time they are through the tubes, and after that they should be got into the chimney as quickly as possible to assist the draft. The height of the chimney should be 26 times the diameter of the flue. This rule may be varied somewhat to suit different localities. Boilers should not be too long. The best experience shows that the length of tubes should be from 45 to 50 times their diameter. The steam space or length of a boiler containing 2½ in. tubes, should not be over 10 ft. long; 3 in. tubes, 12 ft. long; 4 in. tubes, 16 ft. long; and this without reference to the diameter of the shell, add to this length whatever may be required for the flue, or breeching, as usually termed. Keep the shell of the boiler as hot as possible on the outside; do not close the side walls too low down upon the boiler; let the hot gases remain dead as high as possible on the sides and even over the top (except immediately over the grate surface), if convenient to arch it over, having the ends properly protected and enclosed. The boiler is thus kept at a more equal heat, giving dryer steam and adding to its long service, by not causing so much unequal expansion and contraction. Have all exposed surfaces of pipes and boilers well protected with non-heat-conducting material. These points are not claimed as original, but on the contrary they are borrowed from the best engineering practice in the country.

The economy or evaporating capacity of the boilers may be expressed in the number of pounds of water evaporated into dry steam with one pound of coal.

With good hard or soft coal, a tubular boiler set as above, a good draft, and skillful firing, will evaporate 9 to 10 lbs. of water with 1 lb. of coal. The average result is at least 35 per cent. below this.

With these data and a knowledge of the economy of the engine, a close approximation of the fuel consumption may be had, Tubes should not be nearer than 3 in. to the shell, allow sufficient space between for circulation. Have room at the bottom for large manholes to admit of examinations and thorough cleaning. Tubes near the bottom of the shell are of little value for heating

To determine the horse power of a boiler, add together all the heating surface, including the tubes, in square feet and divide by 12, which will give the relative horse power. A boiler for first-class automatic engine, should be large enough to evaporate 30 lbs. of water to each horse power of engine per hour; plain slide valve 40 per cent. more to be of sufficient power.

There are several practical points in reference to the management of *boilers which are* too much overlooked. One of the most important is a

properly made fusible plug and put into the boiler in the right place. It should be made of the best steam metal, filled with U. S. standard Banca tin. For a horizontal tubular boiler, it should be placed at the highest point of fire contact at the back end, above the tubes; for an upright tubular boiler, in the crown sheet of the fire box; in a locomotive boiler, in the back corner of crown sheet in fire box, or at back end. It should be examined internally and externally as often as once a year, and renewed if necessary, but should not be used more than two years without renewal. The safety valve should be lifted once a week and examined as to condition. Observe if the weight is placed right. The boilers should be blown off under pressure twice in the 24 hours, in the morning before starting the engine, and after stopping, or during the night. A surface blow-off is a good thing when the water is bad and much foreign matter is held in solution, particularly if much oil is used in the steam cylinder. Blow out the tubes with steam jet once a week and use a suitable brush or scraper often. Do not allow bunches of oil and dirt to collect on the tubes or shell. Never pump cold water into the boilers if it can be avoided; it is contrary to good engineering and exceedingly injurious to the boiler. Keep the feed water as near the boiling point as possible with a suitable heater, or other convenient methods. As a general thing it is not advisable to go above it. Run your boilers as equal as possible with the water about 6 in. above the tubes. Keep the fires thin (about four inches), and even on the surface. Circumstances may vary these conditions, which will require much good judgment. Examine carefully as often as possible the internal condition of your boilers. See that they are kept clean, and any necessary repairs required have attended to at once. Engineers that attend strictly to these things, save themselves a vast amount of time and anxiety and promote the interests of their employers, and, last but not least, add security to the whole community.

THE STEAM ENGINE.

In regard to the Stationary Steam Engine, there is a great variety of opinion among builders as to the form of construction, style of bed, dimensions and positions of bearings, form of valves, and methods of operating them, whether the engine shall be long or short stroke, high, low or medium speed.

But all are agreed upon these points: that the steam must be hot and dry, that it must come into the cylinder unobstructed, that it must be high pressure to get its expansive effects, and that it must do its work quickly to prevent condensation. Until George H. Corliss introduced his improvements about the year 1848, these points had not been reached, and many of them were unknown. When he made a successful application of the automatic cut-oft to the main valve, as operated and controlled by the governor, so as to produce a perfectly uniform speed, and use at each stroke only as much steam as was required to do the work, and maintain the speed, he made a mark upon the steam engine which will not be obliterated so long as the steam-engine is known. The result was that instead of using 6 lbs. of coal per horse power per hour, as heretofore, with best constructed engines, now only 3 lbs. were used.

In the successful working of the engine the most important point, is to have the valves properly *set*. This matter is not understood sufficiently by those having them in charge. Both employers and employed seem to think that if the engine continues to run, and does the work reasonably well,

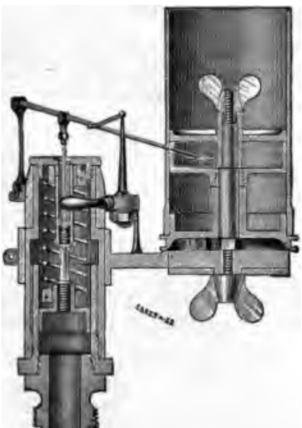
that is about all that is required. This is far from the truth. The only correct method to determine the actual condition of the engine is by the use of the indicator. How many who call themselves *good engineers* know anything about the practical working or the value of this important instrument?

THE INDICATOR AND ITS USES.

It is my purpose in this work to treat of this subject in such a way as to make it plain to the average engineer; how to make use of the Indicator, how to put his valves in proper position for *effective* service, and how to make the necessary calculations to determine the power of his engine, under all conditions. If he cannot do this, he certainly is not competent to take entire charge of machinery of so much importance.

For the purpose of a full understanding of the subject, a cut of the Thompson Improved Indicator is here introduced, with full description; also a series of diagrams, and diagrams from the author's own practice, fully illustrating the difference between an engine in *good* condition and those struggling to do their work under serious difficulties.

INSIDE VIEW.



OUTSIDE VIEW.

General Directions for Using the Thompson Indicator.

Make the connections as short and large as the circumstances will permit, never less than a half-inch pipe with three-fourths inch bends. If side pipe and three-way cock are to be used, open up the cylinder for three-fourths inch pipe (one inch is better) with one inch bends. See that the three-way cock has full capacity so as not to choke the Indicator. Square up the ends of the pipes with the file, ream carefully so as to give a smooth,

even flow of steam and prevent the danger of small particles of the burr blowing off and injuring the Indicator and engine. Blow the pipes out thoroughly before connecting the Indicator. See that it stands vertical and firm; no motion or jar is admissible. Wind some non-conductor (an old woolen shirt, if nothing better offers) around the pipe to prevent condensation.

Keep the engine room at an even temperature, and as high as you can bear to work in comfortably while taking cards.

Now about the drum motion.

Whatever device you use for reducing motions, avoid carrying pulleys as much as possible. You must have straight leads; angular vibrations of drum-line are never to be permitted.

If using the pantograph (which is the most convenient, reliable and durable instrument now in use), get hold of the cross-head where most convenient,—at suitable distance to clear at all parts of stroke, and in line with the post. Place the post at mid-stroke of connections, and at such a distance that it will not shut too close; it must be firm and at such a height that the pantograph-button will be in line with the Indicator leaders. Drop on the pantograph, and try it; if it runs smoothly, and the post does not vibrate or tremble, all right; if it does, find the cause, and remedy it, or your work will be worthless.

Having succeeded in accomplishing so much, now for a card.

Take the Indicator apart, clean and oil it; try every part separately; see if it works smoothly; if so, put it together without spring; lift the pencil lever, and let it fall; if perfectly free, put in the spring, and connect; give it steam, but do not attempt to take a card until it blows dry steam through the relief. (The least particle of water will spoil the work.) Now take cards, but do not close the oil-cup from the steam, as advised by many writers on the Indicator; if you do, you will find you are indicating one engine and running another, especially if the engine be of the Corliss pattern. The valves will stick and jump in all cases more or less, according to pattern of engine and pressure of steam; whereas if lubricated they will run smoothly and evenly. If the oil gums the Indicator, it will soon let you know; so take it off, clean it, and try again.

In measuring cards the planimeter is indispensable. You can approximate the area by the old method, but in all angles where a curved line divides the squares, it becomes more or less a matter of guess-work; while the planimeter, if properly handled, is positively correct to .01 of an inch. As to reading cards, there can be no directions given which amount to anything; common sense and careful reasoning will find the cause that produced the effect. The cause once found will suggest its own remedy.—[American Steam Gauge Company.

AMSLER'S POLAR PLANIMETER.

There are several other instruments which are used as accessories to the Indicator, and which greatly facilitate the use of the instrument, one of which is Amsler's Polar Planimeter, as shown by the accompanying cut, for measuring the area of indicator diagrams. By using this instrument the whole work of measuring a diagram can be done in one minute.

Engineers who have many indicator cards to work up cannot afford to be without a Planimeter.

Directions for Using the Instrument.

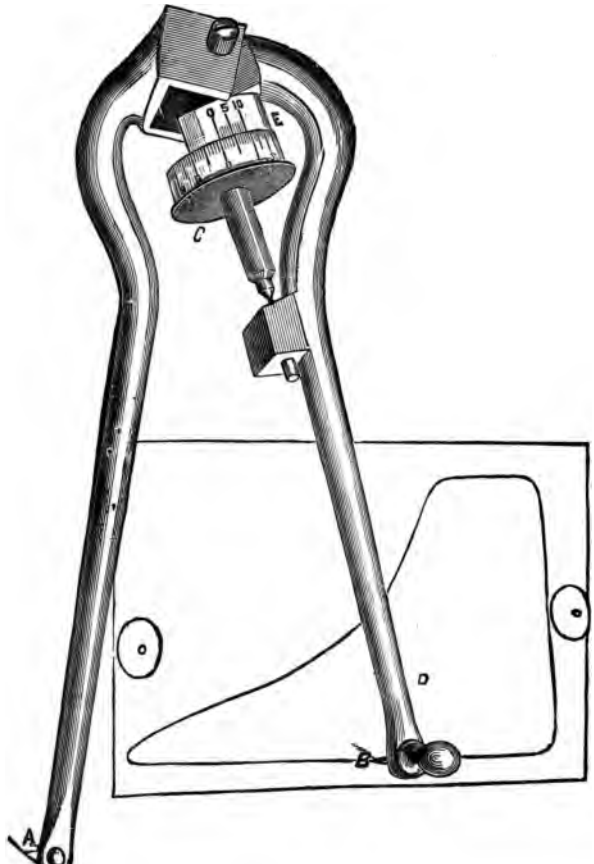
Press the point A slightly into the paper, not clear through, in such position that the *tracer* B will follow the desired line without bringing the

roller C against any projection. The roller must move on a continuous flat surface.

It is also well to fasten the diagram to a drawing-board, or some other flat surface, by means of pins or springs, to prevent it from slipping.

Mark a starting point at any point on the outline of diagram D, set the tracer on that point, and place zero on the roller so it exactly coincides with zero on the vernier E.

THE PLANIMETER.



Now trace the line, moving in the direction travelled by the hands of a watch, stop at the starting point, and take the reading.

1st. Find the highest figure on the roller that has passed the zero on the vernier, moving to the left, which we will assume to be 4; now the construction of the instrument is such, that each figure on the roller represents an equal number of square inches.

2d, Find the number of *completed* divisions between 4 on the roller and zero on the vernier, which we will assume to be 5.

3d, Find the number of the mark on the vernier which coincides with some mark on the roller, which in this case may be 6.

We now have the exact reading, 4.56 or 4 56-100 inches area.

In measuring diagrams of more than 10 inches area, add 10 to the result.

To those who are perfectly familiar with the instrument, it is not necessary to place zeros so they coincide; but take the reading as it is, and subtract from the result. Should the second reading be less than the first, add 10 to the second reading before making the subtraction.

For instance, should the first reading be 8.42, and the second reading 2.68, add 10 to the second reading, thus: 2.68+10=12.68—8.42=4.26 square inches.

If the area to be measured is very large, divide it by lines into areas of less than 20 square inches, and take separate measurements.

If the drawing is to a scale, multiply the result by the square of the ratio number of the scale.

Should we desire to find the area of a plan containing 5 square inches, drawn to a scale of 100 rods to the inch, we square the ratio number, and multiply by 5, thus: 100×100=10,000×5=50,000 square rods.

In using the Planimeter for indicator diagrams, and for which it is *specially* adapted, we find the area of the diagram, according to the foregoing directions, which we will assume to be 2.48; we now measure the length of the diagram parallel with the atmospheric line, which we will say in this case is 4 inches. Now divide the area by the length; the quotient is the mean, or average height of the diagram in inches, which is .62 inches; this we multiply by the scale of the indicator, which we will assume to be 40; the product gives us 24.8 lbs. mean pressure on each square inch of the piston.

Expressed arithmetically 2.48÷4=.62×40=24.8.

It can also be used for measuring any regular or irregular plot or diagram.—[American Steam Gauge Company.

TABLE.

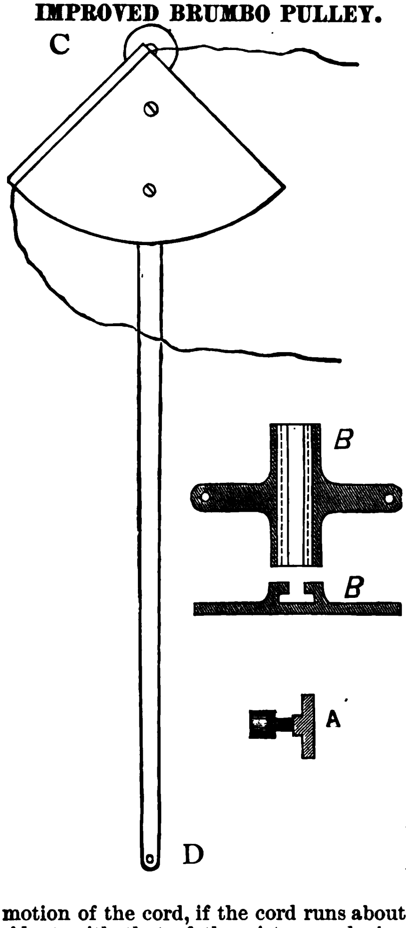
Showing the weight of the atmosphere, in lbs. avoirdupois, on 1 square inch, corresponding with different heights of the barometer, from 28 inches to 31 inches, varying by tenths of an inch.

Barometer in Inches.	Atmosphere in lbs.	Barometer in Inches.	Atmosphere in lbs.	Barometer in Inches.	Atmosphere in lbs.
28.0	13.72	29.1	14.26	30.1	14.75
28.1	13.77	29.2	14.31	30.2	14.80
28.2	13.82	29.3	14.36	30.3	14.85
28.3	13.87	29.4	14.41	30.4	14.90
28.4	13.92	29.5	14.46	30.5	14.95
28.5	13.97	29.6	14.51	30.6	15.00
28.6	14.02	29.7	14.56	30.7	15.05
28.7	14.07	29.8	14.61	30.8	15.10
28.8	14.12	29.0	14.66	30.9	15.15
28.9	14.17	30.0	14.70	31.0	15.19
29.0	14.21				

REDUCING MOTIONS.

Probably the simplest and best reducing motion for general use, is the Improved Brumbo Pulley as illustrated in the following cut. It is simply a narrow bar of wood, at least one and one-half times as long as the stroke of the engine. The cord runs over an arc, the centre of which is the pin on which the bar swings. The radius of the arc, from the swinging point, to give the desired length of the diagram can be readily found by dividing the bar by the stroke and multiplying the quotient by the length of the diagram desired. The product will be the required radius. For example, if the bar is 30 inches long and the stroke 20 inches, and we wish to obtain a 3-inch diagram, we have 30 inches $\div$ 20 inches$=1\frac{1}{2}$, $1\frac{1}{2}\times 3$ inches$=4\frac{1}{2}$ inches, the radius required to give a diagram 3 inches in length. When the cross-head is in the middle of the stroke the swinging bar must be in the middle of its path. This apparatus has but few joints, and is very simple. From suggestions made by Mr. Hill, of Hill, Clarke & Co., Boston. The author has made an improvement as shown in the cut. Instead of a link to connect bar with cross-head, as heretofore used, the lower end of bar is pivoted to a T-headed bolt, A, (or any other convenient devise), which slides in a grooved plate, B. This plate or devise must be attached to the cross-head in such a manner, and the swinging point of the bar should be in such a position that the bar will stand verticle when the piston is at half stroke. The bar also should be so located that when at half stroke, the lower centre will be as much below the line of motion as when at the ends of stroke it is above. It is not essential that the plate should be at the centre of cross-head pin, it may be placed above or below, or forward or back of it, as is most convenient. By this arrangement the motion of the cord, if the cord runs about parallel with the piston rod, is coincident with that of the piston, and gives a correct line upon the diagram, which is not the case with the old plan. (See cut on opposite page.) The same principle is there applied by attaching the end of the swinging bar to the small cross-head D.

IMPROVED BRUMBO PULLEY.

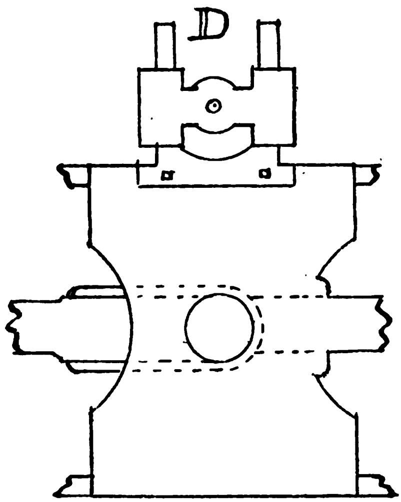


THE PANTOGRAPH.

The Pantograph is quite commonly used as a reducing motion. Although it gives, theoretically, a perfect motion, owing to its complicated construction and many joints, it soon becomes shaky, unless very nicely made, and gives erroneous results. Whatever reducing motion is used, its accuracy can be easily tested in the following manner: Lay off on the guides points at say ¼, ½, ¾, etc., of the stroke. Connect the indicator with reducing motion in the same manner as for taking diagrams. When the cross-head is on either dead center, touch the pencil to the paper and make a vertical mark. In the same way make marks when the cross-head reaches each successive quarter point on the guides. If the marks are exactly at fourths on the card the motion on the cross-head has been accurately reduced. These directions given for reducing motions are general; some special cases require special modifications. Carrying pulleys and long cords should be avoided if possible. It is well to substitute piano wire for cord when any great length has to be used.

REDUCING MOTION.

See bottom page 12.



The indicator having been placed in position and a correct reducing motion obtained, it is next necessary to adjust the length of the cord so that the drum will not strike the stops at either extreme of its rotation. Find about the length of cord required and make a loop at the end, so that when the hook on short piece of cord connected with the indicator is hooked in, the cord will be a little too long. Take up the extra length by tying knots in the cord until the drum rotates without striking either stop. This method may seem rather primitive, but it has been adopted by many of our best engineers after trying the various devices for shortening the cord.

After the cord is adjusted and a paper wrapped on the drum, open the indicator cock and allow the piston to play until the instrument has been thoroughly warmed by the steam, then press the pencil on the paper by the wood handle. After the pencil has remained on the paper during one revolution, draw it back, close the cock, then press the pencil on the paper and take the atmospheric line.

The pressure of the pencil on the paper can be adjusted by screwing

the handle in or out, so that when it strikes the stop there will be just enough pressure on the pencil to give a distinct fine line. The line should not be heavy, as the friction necessary to draw such a line is sufficient to cause errors in the diagram.

After the diagram has been taken, disconnect the cord to avoid any unnecessary wear on the drum.

On locomotives and engines, the speed of which is so great that it is difficult to hook in the loop, arrangements can easily be made so this will not have to be done. At the further end of the arc on the Brumbo pulley, insert an ordinary screw eye. Drive another screw eye firmly into a small hole drilled in the centre of the end of the bolt on which the bar swings. The cord from the indicator can then be carried through the eye at the end of the arc, and then through the eye in the end of the bolt and back to some convenient point near the instrument where it can be easily reached by the operator. Connect the cord with the instrument and draw it through the eyes until the drum will not strike the stops at its extreme positions. Then at the point on the cord just before the eye at the end of the arc, tie a small ring. When the cord is drawn taut by the operator, the ring stops the cord when it has been drawn through just enough to give the proper motion to the drum. As soon as the diagram and atmospheric line have been taken, slacken the cord and the drum will stop. This arrangement is very convenient on locomotives, as the cord can be drawn taut with one hand while the diagram is taken with the other.

Make notes of as many of the following facts as possible: The day and hour of taking the diagram and the scale of the spring used. The engine from which the diagram was taken, which end and from which cylinder if one of a pair. The diameter of the cylinder, the length of the stroke, and the number of revolutions per minute. What per cent. of the piston displacement, the clearance and waste room is at each end of the cylinder. The boiler pressure from the gage, and, if the engine is condensing, the vacuum by the gage, and the temperature of the hot well. If the engine is compound, the pressure in the receiver.

It is often useful to make notes of special circumstances of importance, such as a description of the boiler, diameter and length of steam and exhaust pipes, temperature of the feed water, the quantity of water and fuel consumed per hour, etc. On a locomotive find the exact circumference of the drivers, by measuring on the track the exact distance passed over during a complete revolution. Note also the position of the throttle and the link, the size of the blast orifice, the weight of the train, and the gradient.

On diagrams from marine engines, note, in addition to the general facts, the speed of the ship in knots per hour, the direction and force of the wind, the direction and state of the sea, the diameter and pitch of the screw, the kind of coal, the amount consumed and the ashes made per watch.—[Crosby Steam Gage and Valve Co.

INDICATOR DIAGRAMS.

The degree of excellence to which the steam engines of the present time have attained, is due more to the use of the indicator than to any other one thing, as a careful study of indicator diagrams taken under different conditions of load, pressure, etc., is the only means of becoming familiar with the action of steam in an engine, and of gaining a definite knowledge of the various changes of pressure that take place in the cylinder.

An indicator diagram is the result of two movements, namely: a *horizontal movement* of the paper and a vertical movement of the pencil, and

consequently represents by its length the stroke of the engine on a reduced scale, and by its height at any point, the pressure on the piston at a corresponding point in the stroke.

The pressure shown is measured by a scale graduated to correspond with the spring used.

The most common scales are those numbered 40, 50 and 60; that is, an inch vertical height on the diagram represents, according to the spring used, 40, 50 or 60 pounds of steam per square inch in the cylinder.

A single diagram shows the pressure acting on one side of the piston during both the forward and return stroke, with all the changes of pressure properly located in the stroke. To show the corresponding pressure on the other side another diagram must be taken from the other end of the cylinder. When the three-way cock is used, the diagrams from both ends are usually taken on the same paper, as in Fig. 2.

Fig. 1.

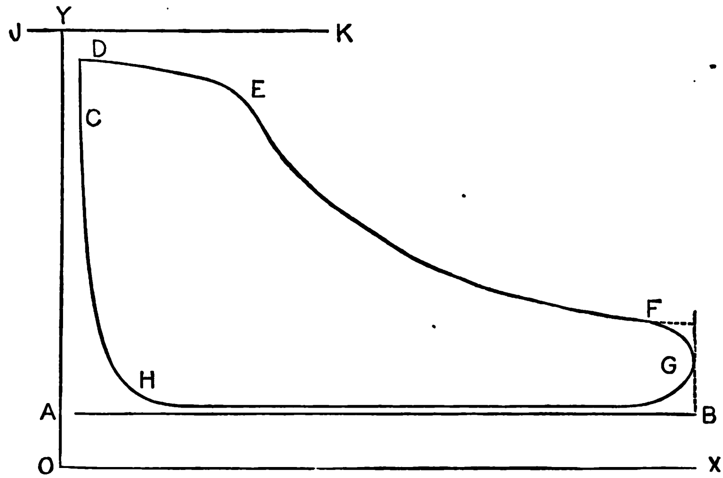


Diagram from an improved Greene engine. Cylinder, 16 inches in diameter, 36 inches stroke. Boiler pressure, 100 lbs. 80 revolutions per minute. Scale 50.

DEFINITIONS.

The names which have been given to the various points and lines on the diagram are as follows (see Fig. 1) :—

The Atmospheric Line, A B, is a line drawn by the pencil of the indicator when the connections with the engine are closed and both sides of the piston are open to the atmosphere. This line represents on the card the pressure of the atmosphere, or zero gage pressure.

The Vacuum Line, O X, is a reference line usually drawn about 14 7-10 pounds by scale below the atmospheric line. It represents a perfect vacuum, or absence of all pressure.

The Clearance Line, O Y, is another reference line drawn at a distance from the end of the diagram equal to the same per cent. of its length as the clearance and waste room is of the piston displacement. The distance be-

tween the clearance line and the end of the diagram represents the volume of the clearance and waste room of the ports and passages at the end of the cylinder.

The Line of Boiler Pressure, J K, is drawn parallel to the atmospheric line, and at a distance from it by scale equal to the boiler pressure shown by the gage. The difference in pounds between it and D E shows the loss of pressure due to the steam pipe and the ports and passages in the engine.

The Admission Line, C D, shows the rise of pressure due to the admission of steam to the cylinder by opening the steam valve. If the steam is admitted quickly when the engine is about on the dead centre, this line will be nearly vertical.

The Steam Line, D E, is drawn when the steam valve is open and steam is being admitted to the cylinder.

The Point of Cut-Off, E, is the point where the admission of steam is stopped by the closing of the valve. It is difficult to determine the exact point at which the cut-off takes place. It is usually located where the outline of the diagram changes its curvature from convex to concave.

The Expansion Curve, E F, shows the fall in pressure as the steam in the cylinder expands doing work.

The Point of Release, G, shows when the exhaust valve is open.

The Exhaust Line, F G, represents the change in pressure that takes place when the exhaust valve opens.

The Back Pressure Line, G H, shows the pressure against which the piston acts during its return stroke. On diagrams taken from non-condensing engines it is either coincident with or above the atmospheric line, as in Fig. 1. On cards taken from a condensing engine, however, it is found below the atmospheric line, as in Fig. 2, and at a distance greater or less according to the vacuum obtained in the cylinder.

The Point of Exhaust Closure, H, is the point where the exhaust valve closes. It cannot be located very definitely, as the change in pressure is at first due to the gradual closing of the valve.

The Compression Curve, H C, shows the rise in pressure due to the compression of the steam remaining in the cylinder after the exhaust valve has closed.

The Mean Effective Pressure (M. E. P.) is the mean net pressure urging the piston forward.

The Initial Pressure is the pressure acting on the piston at the beginning of the stroke.

The Terminal Pressure is the pressure above the line of perfect vacuum that would exist at the end of the stroke if the steam had not been released earlier. It is found by continuing the expansion curve to the end of the diagram, as in Fig. 5. This pressure is always measured from the line of perfect vacuum, hence it is the *absolute* terminal pressure.—[Crosby Steam Gage and Valve Co.

HORSE POWER.

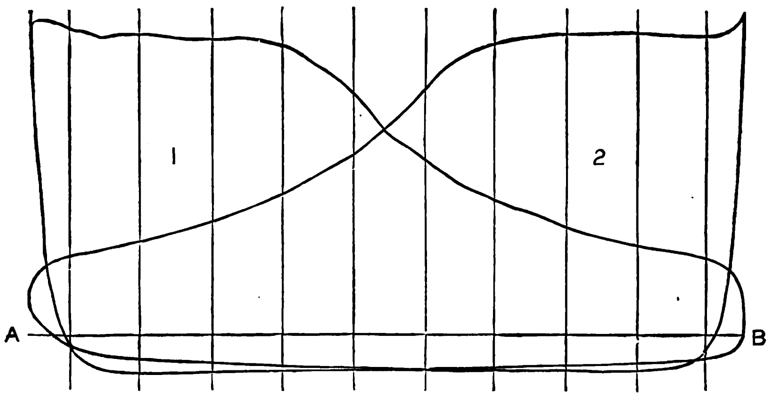
Watt ascertained by experiment that the power of London draught horses, exerted with ordinary continuance, was to lift 33,000 lbs. one foot in one minute. This is now the standard to determine the horse power of an engine. The standard horse power, as above stated, is 33,000 ft. lbs. A foot lb. is 1 lb. lifted 1 ft. high per minute, or equivalent amount of force, or 12 lbs. lifted 1 inch per minute. To calculate the horse power, multiply the area of the piston in square inches, by twice the length of the stroke in feet, and the product by the number of revolutions per minute. This product is known as the "Piston Displacement." Divide this product by

33,000 and the result is the "Horse Power Constant," or the power developed for every pound of Mean Effective Pressure (abbreviated M. E. P.) Multiply the quotient by the M. E. P., ascertained from the diagram as hereafter explained, and the result is the indicated horse power. It is convenient for the engineer to know the Horse Power Constant of his engine. Suppose it is 20 x 30 inches, making 120 revolutions per minute, thus:

```
                  Area of piston,   314.16 sq. inches,
  Multiplied by twice the stroke,        5 feet,
                                  --------
                                  1,570.80
   Multiplied by rev. per minute,      120
                                  --------
Divided by standard of H. P. 33,000)188496.00(5.712 H. P. Constant.
                                   165000        40 lbs. M. E. P.
                                   ------     -------
                                   234960  228.480 I. H. P.
                                   231000
                                   ------
                                     39600
                                     33000
                                     -----
                                      66000
                                      -----
                                      66000
```

There are several approximate methods for computing the mean effective pressure. One of the most convenient is as follows: Draw on the diagram ten, or any convenient number of lines, as in Fig. 2, perpendicular

Fig. 2.



Diagrams from Hartford engine. Cylinder, 16 x 24 inches. Boiler pressure, 87 lbs. Vacuum per gage, 23½ inches. 130 revolutions per minute. Scale, 50.

to the atmospheric line and equal distances apart. The first and last of these ordinates are drawn half of the distance from the ends of the diagram that each ordinate is from another, as the height of each is supposed to represent *the average* height of the space in the middle of which it

stands. Measure the length of each ordinate within the lines of the diagram, and divide the sum of their lengths by the number of ordinates used. Multiply the average length thus found by the scale of the spring used, and the result will be the mean effective pressure of the diagram. It is sometimes convenient to find the sum of the lengths of the ordinates by using a sliding rule, or by marking off the different lengths successively on a strip of paper.

Fig. 3.

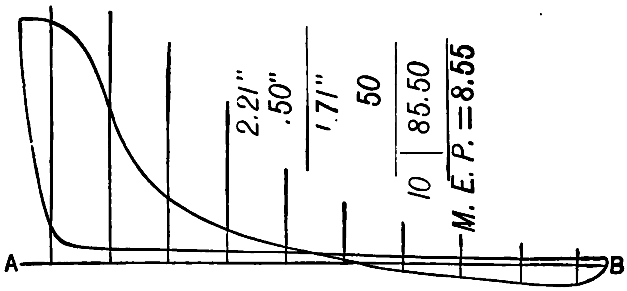


Diagram from Buckeye engine. Cylinder, 16 x 32 inches. 100 revolutions per minute. 50 scale.

In case there is a loop in the diagram, as in Fig. 3, caused by the steam expanding below the back pressure line, when the engine is non-condensing, the ordinates below the back pressure line are negative, and the sum of their lengths must be subtracted from the sum of the lengths of the ordinates above back pressure.

To Calculate the Horse Power of an Engine.—Multiply the mean net area of the piston in square inches, by the mean effective pressure (M. E. P.) in pounds per square inch acting on the piston throughout the strokes in both directions, ascertained from indicator diagrams taken from both ends of the cylinder. Multiply this product by the distance through which the piston travels in feet per minute and divide by 33,000.

$$\text{Thus, I.H.P} = \frac{\text{Mean net area of piston} \times \text{M.E. P.} \times \text{revs. per min.} \times 2 \times \text{stroke}}{33{,}000.}$$

When there are a number of diagrams taken from the same engine to be worked up, the calculations may be simplified by multiplying the area of the piston by twice the length of the stroke, and dividing the result by 33,000. This gives the "constant of the engine," that is, the power that would be developed at one revolution per minute with one pound mean effective pressure. Multiply this constant by the number of revolutions per minute, and then by the mean effective pressure, and the product will be the I. H. P. If the number of revolutions is the same for several diagrams as is frequently the case with stationary engines, the calculation may be still further simplified by multiplying the "*constant of the engine*" by the number of revolutions per minute. This will give the "*Horse Power Constant*," or the horse power developed per pound M. E. P. Multiply the Horse Power Constant by the M. E. P., and the product will be the *Indicated Horse Power* (I. H. P.)

THEORETICAL CURVE.

It is sometimes interesting to compare the expansion curve of the diagram with the theoretical curve that would be drawn if the steam was a perfect gas expanding under perfect conditions. The rectangular hyperbola, which is easily drawn, serves very well as an approximation to the ideal curve. If it is required to have the theoretical curve coincide with

Fig. 4.

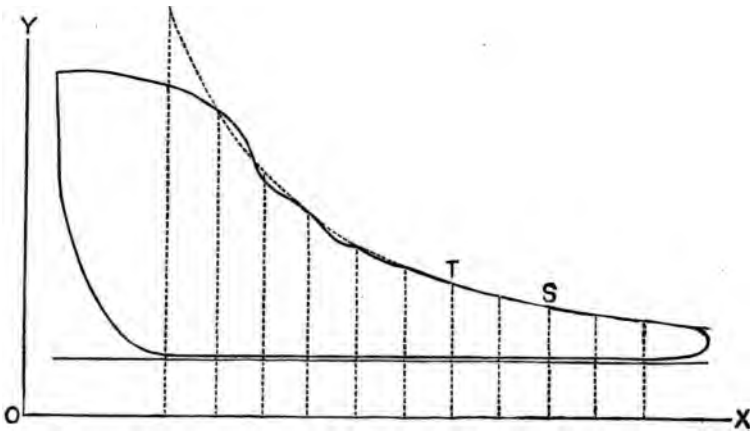


Diagram from Porter-Allen engine. Cylinder 11¼ x 20 inches. 230 revolutions per minute. Scale 50. Clearance, 4½ per cent.

the expansion curve at any point, as at S, the properties of the hyperbola are such, if the distance of S from O Y, the clearance line, be multiplied by the height of S above O X, the vacuum line, the height of any other point on the theoretical curve can be found by dividing this product by the distance of the point from O Y.

For example (see Fig. 4): S is 2.75 inches from O Y and .58 of an inch from O X. $2.75 \times .58 = 1.595$.

To find the height of a point, T, above O X, which is 2.25 inches distant from O Y, divide the constant. 1.595 by 2.25, and we have .71, which is the required height in inches of the point above O X.

In the same way other points can be located, and a curve drawn through them will be the required theoretical curve, as shown in Fig. 4. The theoretical curve will often come much higher at one end or the other, above the expansion curve, than it does on the diagram in the figure. The initial point of the theoretical curve may be taken at any point on the expansion curve, but it is usually best to take it just before the point of release.

STEAM CONSUMPTION.

When comparing the economy of the steam engines, and estimating the *loss due to the* mal-adjustment of the valves, it is often instructive to know

the amount of steam consumed per horse power per hour that is accounted for by the indicator diagram. The steam not being a perfect gas or vapor, but usually having more or less water mechanically mixed with it, and also being subject to loss of heat by radiation, and loss from condensation and re-evaporation in the cylinder, the rate of steam consumption shown by the indicator diagram is almost always considerably below the actual rate found by weighing the water fed to the boiler.

We give a convenient rule and computation table compiled by Edwin F. Williams, M. E., for determining the amount of steam consumed per horse power per hour accounted for by the indicator diagram. To use the rule it is only necessary to know the mean effective pressure. and the absolute terminal pressure of the diagram to be computed.

Rule. Find the weight per cubic foot of steam in column 4 corresponding to the absolute terminal pressure of the diagram in column 3. Divide this weight by the *rate number* found in column 2 opposite the mean effective pressure in column 1. Multiply the quotient by the constant number 32.32, and the product will be the weight of dry steam per indicated horse power per hour, subject to correction for clearance and compression, which may be done by Mr. J. W. Thompson's method as follows: Fix the terminal pressure at point O, Fig. 5, where it would have been if the steam

Fig. 5.

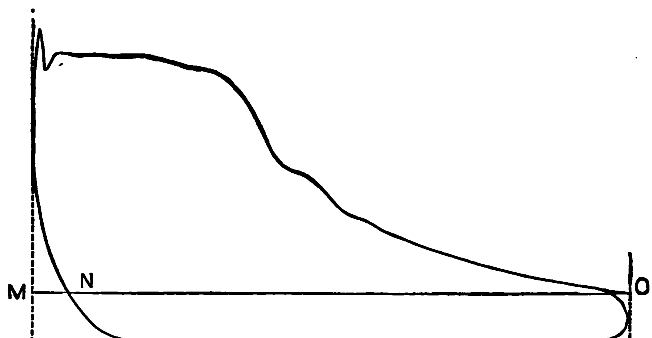


Diagram from Porter-Allen engine. Cylinder, 22 x 36 inches. 140 revolutions per minute. Scale, 50.

had not been released until the end of the stroke was reached. Second, draw the line O M parallel with the atmospheric line. It cuts the compression curve at N, at which point the quantity of steam exhausted from the clearance has been restored, and the consumption will be as much less than the rule shows as the line O N is shorter than the line O M. Third, multiply the result obtained by the rule, by the length of the line O N, and divide by the length of O M. The result will be the rate of steam consumption, corrected for clearance and compression.

Following is the Computation Table:—

STANDARD RATES.		Col. 3. Terminal Pressures Absolute.	Col. 4. Weight per Cubic foot.
Col. 1. M. E. P.	Col. 2. Rate.		
5	.0117		
6	.0141		
7	.0164	5	.0138
8	.0188	6	.0163
9	.0211	7	.0189
10	.0235	8	.0214
11	.0258	9	.0239
12	.0285	10	.0264
13	.0305	11	.0289
14	.0329	12	.0314
15	.0352	13	.0338
16	.0376	14	.0362
17	.0399	15	.0387
18	.0423	16	.0411
19	.0446	17	.0435
20	.0470	18	.0459
21	.0493	19	.0483
22	.0517	20	.0507
23	.0540	21	.0531
24	.0564	22	.0555
25	.0586	23	.0580
26	.0611	24	.0601
27	.0634	25	.0625
28	.0658	26	.0650
29	.0681	27	.0673
30	.0705	28	.0696
31	.0728	29	.0719
32	.0752	30	.0734
33	.0775	31	.0766
34	.0799	32	.0789
35	.0822	33	.0812
36	.0846	34	.0835
37	0869	35	.0858
38	.0893	36	.0881
39	.0916	37	.0905
40	.0940	38	.0929
41	.0963	39	.0952
42	.0987	40	.0974
43	.1010	41	.0996
44	.1034	42	.1020
45	.1057	43	.1042
46	.1081	44	.1065
47	.1104	45	.1089
48	.1128	46	.1111
49	.1151	47	.1133
50	.1175	48	.1156
51	.1198	49	.1179
52	.1222	50	.1202
53	.1245	51	.1224
54	.1269	52	.1246
55	.1292	53	.1269
56	.1316	54	.1291

EXAMPLE OF WILLIAMS' RULE.

EXAMPLE.—In Fig. 5, the absolute terminal pressure of the diagram is 28, and the mean effective pressure is 42 pounds. The weight per cubic foot at the terminal (col. 4) is .0696. The rate number in col. 2 opposite the M. E. P. is .0987. Then by the rule,

$$.0696 \div .0987 \times 32.32 = 22.79.$$

which is the number of pounds of steam per indicated horse power per hour, not taking clearance and compression into account.

The line O M is 3.14 inches in length, and the line O N is 2.95 inches; then to correct for clearance and compression,

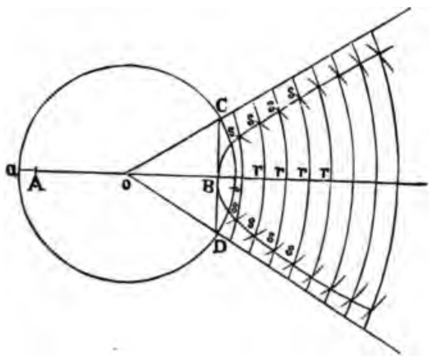
$$22.79 \div 3.14 \times 2.95 = 21.41 \text{ pounds,}$$

which is the amount of steam per horse power per hour, accounted for by the indicator, corrected for both clearance and compression.—[Crosby S. G. and V. Co.

TO DESCRIBE AN HYPERBOLA.

A method of describing this curve, with cut, is here given, for the purpose of enabling those not familiar with drawing the curve, to get a better idea of its properties.

It has no special reference to the indicator diagrams shown, but will be of some assistance to those desiring to make the theoretical expansion curve. One half of the curve shown would be the form of the expansion line. From the point of cut-off, to the end of stroke in a diagonal line, would be the transverse diameter. The diameter of the cylinder would be the conjugate.

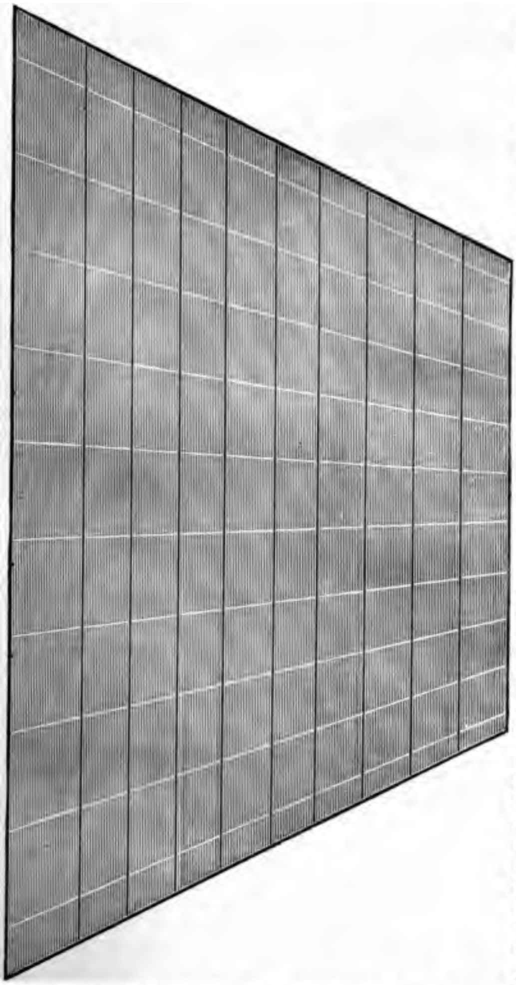


Let A B equal the longest or transverse diameter, and C D, perpendicular to it, the conjugate, and let the line A B be produced or extended from its respective limits each way, as to *a*, *r*, *r*, etc. Bisect A B in *o*, and with the radius *o* C, or *o* D, and *o* as the centre, describe the circle C *e* D *a*. Divide A B produced from B, into any number of parts, as *r*, *r*, *r*, etc., and with the radii A *r* and B *r*, and the foci *a* and *e* as centres, describe arcs cutting each other as in *s s*, etc. The intersections of the arcs with each other will define the curve of the hyperbola.

CALCULATING DIAGRAMS.

The use of the planimeter is the best method of obtaining the correct area of a diagram, but when this is not at hand the following constructed scale is simple, very correct, and easily learned.

Fig. 0.



For a small diagram not over 5 inches long, the scale (Fig. 0), full size, will answer the purpose.

The diagonal white lines are divided into equal divisions or spaces as seen. The parallel black lines are to facilitate the placing of the diagram upon the scale.

Take the diagram from the indicator, draw two perpendicular lines the length of the card, and cut off the bottom parallel with the atmospheric line. Place the bottom edge parallel on the scale at the right position to get the length of the diagram. Mark the divisions to correspond with the white lines, the two end spaces being only half as wide as the others. Measure with the scale corresponding with the spring, the distance from atmospheric line (if a non-condensing engine, if condensing from indicated vacuum line) to the steam line at each point of division, add the whole together, point off one decimal to the right, which divides it by ten, the number of divisions, and gives the M. E. P. in lbs. and tenths for that end. Take the other end in the same way, add them together and divide by two, which gives M. E. P. This result multiplied by "Constant" at 1 lb., pressure, gives the horse power. If the steam line falls below the atmospheric line that portion is negative and must be deducted as shown in Fig. 3, page 18.

Indicated Horse-Power for each Pound Average Pressure on a Square Inch, with Different Diameters and Speeds of Pistons.

Diameter of Cylinder.	Speed of Piston in Feet a Minute.									
	240	300	350	400	450	500	550	600	650	750
inches.										
4	.091	.114	.133	.152	.171	.19	.209	.228	.247	.285
4½	.115	.144	.168	.192	.216	.24	.264	.288	.312	.36
5	.144	.18	.21	.24	.27	.30	.33	.36	.39	.45
5½	.173	.216	.252	.288	.324	.36	.396	.432	.468	.54
6	.205	.256	.299	.342	.385	.428	.471	.513	.555	.641
6½	.245	.307	.391	.409	.461	.512	.563	.614	.698	.800
7	.279	.348	.408	.466	.524	.583	.641	.699	.756	.874
7½	.321	.401	.468	.534	.602	.669	.735	.802	.869	1.002
8	.365	.456	.532	.608	.685	.761	.837	.912	.989	1.121
8½	.413	.516	.602	.688	.774	.86	.946	1.032	1.118	1.29
9	.462	.577	.674	.770	.866	.963	1.059	1.154	1.251	1.444
9½	.515	.644	.751	.859	.966	1.074	1.181	1.288	1.395	1.610
10	.571	.714	.833	.952	1.071	1.190	1.309	1.428	1.547	1.785
10½	.63	.787	.919	1.050	1.181	1.313	1.444	1.575	1.706	1.969
11	.691	.864	1.008	1.152	1.296	1.44	1.584	1.728	1.872	2.160
11½	.754	.943	1.1	1.257	1.414	1.572	1.729	1.886	2.043	2.357
12	.820	1.025	1.195	1.366	1.540	1.708	1.880	2.050	2.222	2.564
13	.964	1.206	1.407	1.608	1.809	2.01	1.211	2.412	2.613	3.015
14	1.119	1.398	1.631	1.864	2.097	2.331	2.564	2.797	3.029	3.495
15	1.285	1.606	1.873	2.131	2.409	2.677	2.945	3.212	3.479	4.004
16	1.461	1.827	2.131	2.436	2.741	3.045	3.349	3.654	3.958	4.567
17	1.643	2.054	2.396	2.739	3.081	3.424	3.766	4.108	4.450	5.135
18	1.849	2.312	2.697	3.083	3.468	3.854	4.239	4.624	5009	5.78
19	2.061	2.577	3.006	3.436	3.865	4.295	4.724	5.154	5.583	6.442
20	2.292	2.855	3.331	3.807	4.285	4.759	5.234	5.712	6.186	7.138
21	2.518	3.148	3.672	4.197	4.722	5.247	5.771	6.296	6.820	7.869
22	2.764	3.455	4.031	4.607	5.183	5.759	6.334	6.911	7.486	8.638
23	3.021	3.776	4.405	5.035	5.664	6.294	6.923	7.552	8.181	9.44
24	3.289	4.111	4.797	5.482	6.167	6.853	7.538	8.223	8.908	10.279

25	3.569	4.461	5.105	5.948	6.692	7.436	8.179	8.923	9.566	11.053
26	3.861	4.826	5.630	6.435	7.239	8.044	8.848	9.652	10.456	12.065
27	4.159	5.199	6.066	6.932	7.799	8.666	9.532	10.399	11.265	12.998
28	4.477	5.596	6.529	7.462	8.395	9.328	10.261	11.193	12.125	13.991
29	4.805	6.006	7.007	8.008	9.009	10.01	11.011	12.012	13.013	15.015
30	5.141	6.426	7.497	8.568	9.639	10.71	11.781	12.852	13.923	16.065
31	5.486	6.865	8.001	9.144	10.287	11.43	12.573	13.716	14.866	17.145
32	5.846	7.308	8.526	9.744	10.962	12.18	13.398	14.616	15.834	18.270
33	6.216	7.770	9.065	10.360	11.655	12.959	14.245	15.54	16.835	19.425
34	6.59	8.238	9.611	10.984	12.357	13.73	15.103	16.476	17.849	20.595
35	6.993	8.742	10.199	11.656	13.113	14.57	16.027	17.484	18.941	21.855
36	7.401	9.252	10.794	12.336	13.878	15.42	16.962	18.504	20.046	23.130
37	7.819	9.774	11.403	13.032	14.861	16.29	17.919	19.548	21.177	24.435
38	8.246	10.308	12.026	13.744	15.462	17.18	18.898	20.616	22.334	25.770
39	8.648	10.86	12.67	14.48	16.29	18.1	19.91	21.62	23.53	27.15
40	9.139	11.424	13.328	15.232	17.136	19.04	20.944	22.848	24.752	28.560
41	9.604	12.006	14.007	16.008	18.009	20.00	22.011	24.012	26.013	30.015
42	10.065	12.594	14.693	16.792	18.901	20.99	23.089	25.188	27.287	31.485
43	10.56	13.20	15.4	17.6	19.8	22.0	24.2	26.4	28.6	33.0
44	11.046	13.818	16.121	18.424	20.727	23.03	25.333	27.636	29.939	34.545
45	11.563	14.454	16.863	19.272	21.681	24.09	26.399	28.908	31.317	36.135
46	12.086	15.128	17.626	20.144	22.662	25.18	27.698	30.216	32.754	37.770
47	12.614	15.768	18.396	21.024	23.652	26.28	28.908	31.536	34.164	39.420
48	12.846	16.446	19.187	21.928	24.669	27.41	30.151	32.152	35.633	41.115
49	12.913	17.142	19.999	22.856	25.713	28.57	31.427	34.284	37.141	42.855
50	14.28	17.85	20.825	23.8	26.775	29.75	32.725	35.7	38.675	44.625
51	14.832	18.54	21.665	24.76	27.855	30.95	34.045	37.08	40.205	46.425
52	15.437	19.296	22.512	25.728	28.944	32.16	35.376	38.592	41.808	48.240
53	16.041	20.052	23.394	26.736	30.078	33.42	36.762	40.104	43.446	50.13
54	16.656	20.82	24.29	27.76	31.23	34.7	38.17	41.64	45.11	52.05
55	17.275	21.594	25.193	28.792	32.391	35.99	39.589	43.188	46.787	53.985
56	17.909	22.386	26.117	29.848	33.579	37.31	41.041	44.772	48.503	55.965
57	18.557	23.196	27.062	30.928	34.794	38.66	42.526	46.392	50.258	57.99
58	19.214	24.018	28.021	32.024	36.027	40.03	44.033	48.036	52.039	60.045
59	19.902	24.852	28.994	33.136	37.278	41.42	45.562	49.704	53.846	62.13
60	20.558	25.698	29.981	34.264	38.547	42.83	47.113	51.396	55.679	64.245

TABLE OF HORSE POWER CONSTANT.

For convenience of making calculations, a Table of Horse Power Constant for varied sizes of cylinder and different speeds of piston per minute is given on pages 24 and 25, (arranged by W. A. Hammett, M. E.,) for calculating the diagrams given with planimeter from page 10, or scale on page 23.

Having learned how to apply the Indicator and having understood its reading by means of the preceding illustrations, it is only necessary after taking a diagram to see by careful study where improvement can be made. If your engine is high speed, you will require more lead to your steam valves, and more compression to your exhaust, than for a low speed. If the piston speed is 600 ft. per minute or more, the compression line where it intersects the admission line, should be about one-half the height of the card if non-condensing, if condensing somewhat less. If the piston speed is not more than 450 ft. per minute, one-sixth the height of the card would be sufficient, particularly if the point of cut-off is not more than one-fourth of the stroke.

SETTING OF VALVES.

In setting the valves for the first time of a newly set-up engine, after equalizing the length of the eccentric rod so that the valves will open equal, to have the engine run *forward*, or over, that is, standing at the back end of the cylinder, facing the fly-wheel, the top of which runs from you (if forward) set the throw of the *eccentric forward of the crank*, so that the valve will open the steam port about 1-32 of an inch if a long stroke, and piston speed about 400 ft. per minute, increase the lead as the speed of piston of engine is increased until you may have on a high speed locomotive as much as ⅜in. lead. To run an engine backwards, or under, you have only to set the throw of the eccentric back of the crank instead of forward, as in the other case.

THE KIND OF INDICATOR.

Engineers, like other people, have their preferences, and generally would speak well of the instrument they have been accustomed to use. The author of this work has used the "Crosby" more than any other, but has also used the "Thompson," and the "Tabor." and has found all these instruments well adapted to *high speed* and *pressure*, they also work equally well for low speed and pressure. Care should always be taken in using any instrument, to adapt the spring to the pressure, as explained on page 28; also use a drum the right diameter to produce a proper proportioned card. A slow moving engine with long stroke, requires a larger drum than a quick moving engine with a short stroke. The object being to get a card of good proportions as to length and height, to facilitate measurement with accuracy. Many run to both extremes in the size of cards.

Some indicators are made with a large and small drum interchangable, this is very convenient where the engineer is required to indicate several kinds of engines.

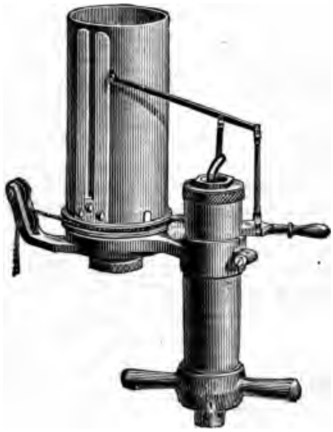
With one pair of instruments and two drums to each, he has what is *equivalent to four* instruments. We think it better to use an indicator at

each end of the cylinder, rather than one in the centre, thus avoiding a three-way cock and long pipe connections, which causes condensation.

Views of the " Thompson " indicator have been given on page 8. A cut of the "Crosby" and also of the "Tabor" is here introduced. The purchaser can thus have a choice of *three first-class instruments.*

CROSBY INDICATOR.

TABOR INDICATOR.



There are some additional advantages not previously mentioned, which seems more fully to develop the subject, as shown in the following extract.

"The steam engine indicator is an instrument for drawing a diagram on paper which shall accurately represent the various changes of pressure on the piston of the steam engine during both the forward and return stroke. The indicator was invented by James Watt, and was extensively used by him in perfecting his engines. Of the earlier forms of the instrument it may simply be said that they were unfit for use on engines running at any but the very slowest speeds. Even then, owing to their many imperfections, their indications were often misleading, and of little use, beyond showing the points in the stroke at which the valves opened and closed; a service of great value, but affording only a small part of the information to be gained from a really good instrument. The Richards Indicator, designed by Mr. Charles B. Richards, contained many improvements on the instruments previously used. It was well adapted to engines running at the speeds commonly employed at the time it was invented, and was for years the standard indicator in both Europe and America. The weights of the moving parts of this instrument are, however, so great that their inertia and momentum seriously affect the accuracy of the diagrams, and render it unfit for use under the conditions of high pressures and high speeds met with in ordinary practice at the present time. Some of the leading items of information to be obtained by the use of the indicator are:—

The arrangement of the valves for admission, cut-off, release and compression of steam.

The adequacy of the ports and passages for admission and exhaust, and when applied to the steam chest, the adequacy of the steam pipes.

The suitableness of the valve motion in point of rapidity at the right time.

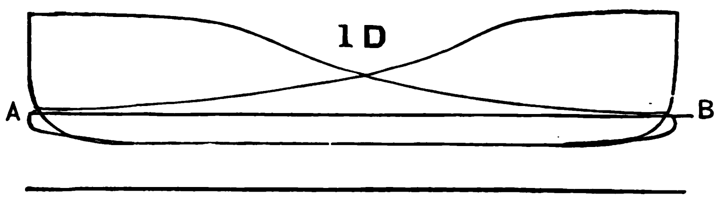
The quantity of power developed in the cylinder, and the quantity lost in various ways—by wire drawing, by back pressure, by permature release, by mal-adjustment of valves, leakage, etc.

It is useful to the designers of steam engines in showing the redistribution of horizontal pressures at the crank pin, through the momentum and inertia of the reciprocating parts, and the angular distribution of the tangential component of the horizontal pressure; in other words, the rotative effect around the path of the crank.

Taken in combination with measurements of the exhaust steam, with the amount of fuel used, the indicator furnishes many other items of importance when the economical generation and use of steam are considered.—[Crosby S. G. and V. Co.

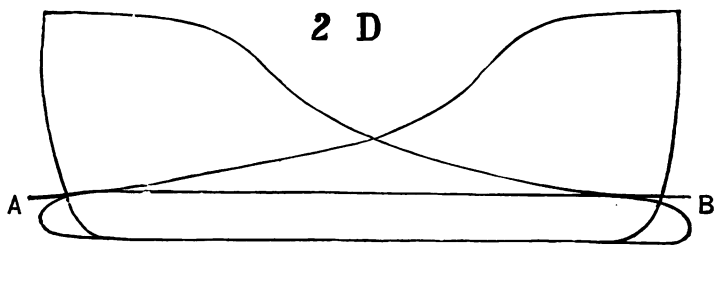
INDICATOR SPRINGS.

The spring of the Indicator should be the proper proportion to the pressure of the steam used, so that the diagram would not be more than 1¾ inches high at the admission line. To illustrate: figures 1, 2, 3 D, represent cards taken from a Hartford engine, each showing about the same amount of work, but quite different in appearance.



Steam, 30 lbs. Vacuum, 20 in. M. E. P., 20 lbs. I. H. P., 112.20

Figure 1 D, a 50 spring or scale, as usually called.

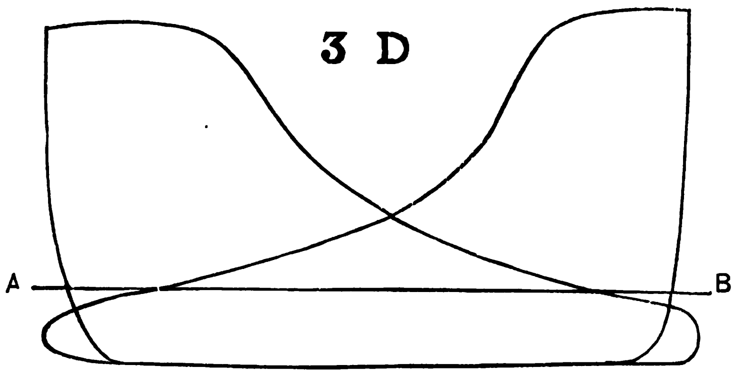


Steam, 36 lbs. Vacuum, 20 in. M. E. P., 19.9 lbs. I. H. P., 111.63.

Figure 2 D, a 30 scale.

The first shows the steam as following too far before cutting off (although the initial pressure is but 30, and the load is a trifle greater than the other cards. This accounts in a great measure for the relative difference). Figure 3 D, with a 20 spring, shows the card as much too high as Fig. 1 is *too low*. The point wished to make clear, is that the steam pressure *should* exceed the spring sufficient to show the card about 1¾ inches high.

Figure 2 with a spring of 30, is about that proportion of diagram, and more liable to be correct.

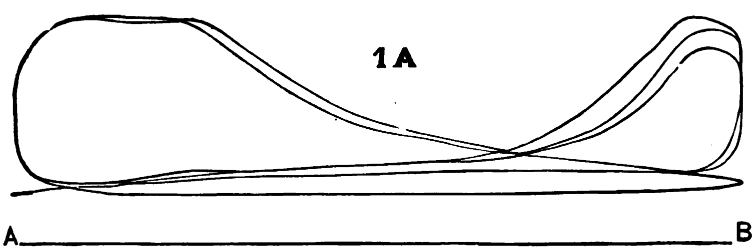


Steam, 35 lbs. Vacuum, 21 in. M. E. P., 19.7 lbs. I. H. P., 110.51.

Figure 3 D, a 20 scale.

NOTE. [To simplify the following diagrams, the back pressure is included with the M. E. P., but the amount of B. P. is stated.]

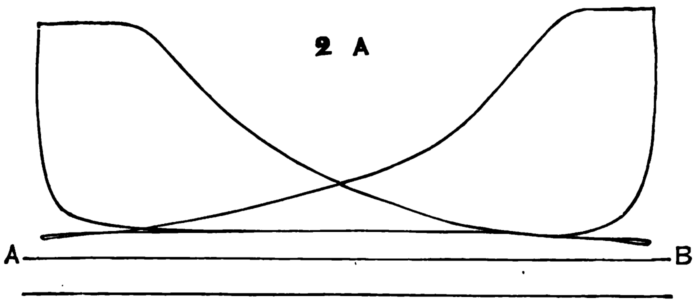
In diagrams 1 and 2 A, we have cards taken from a pair of Wheelock engines 24x48 inches, making 57 revolutions per minute. They had been running 12 years and had never before had an indicator applied. The engineer considered that the valves were right and the engines doing their duty well, which was generally about 300 horse power. Card 1 A, was



Head end steam,	73 lbs.	Crank end steam,	73 lbs.
Back pressure,	13.3 "	Back pressure,	17.5 "
M. E. P.,	37. "	M. E. P.,	25.2 "
I. H. P.,	234.21	I. H. P.,	157.50
Less back pressure I. H. P.,	149.38	Less back pressure,	48.12

the first taken from the left-hand cylinder. The average of the head end shows that it is doing about double the work that the average of the crank end is doing, for there are three distinct lines on the latter, and the gov-

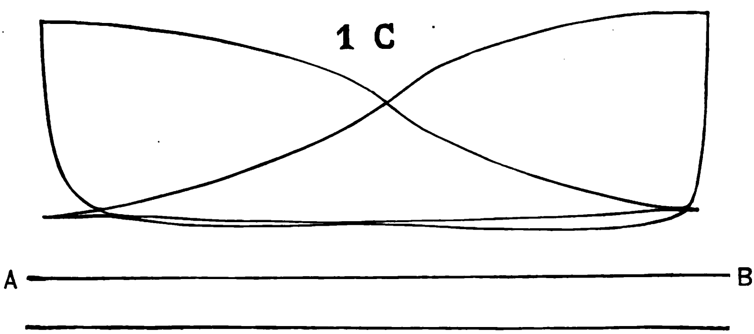
ernor is making spasmodic efforts to keep one end at uniform speed with the other. Had not this engine been one of a pair connected together and working similarly (the serious imperfections being in the same ends in each cylinder, and also connected with two water wheels, which assisted very much in controlling the speed), it is easy to see that the effect would have been disastrous. Card 2 A, shows the same cylinder after the valves



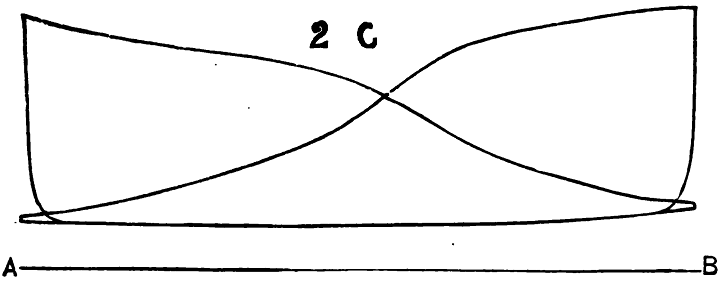
Both ends steam, 73 lbs. Back pressure, 7.17 lbs. M. E. P., 27.7 lbs. I. H. P., 173.12. Less back pressure, 128.12.

had been properly set by the indicator. The most of the adjustment was made while the engine was running and doing its work, the valves of course not having been seen. The gross horse power, including back pressure of card 1 A, is 391.71, while that of 2 A is but 173.12, showing 218.59 H. P. in favor of 2 A, on gross power, and a difference of 69.38 on net power. About the same power was required for the regular work in each case.

These cards were taken August 30th and September 1st, 1883, just previous to the great drought and low water of that year. Had not the indicator been applied and changes made as designated, the engine could not have possibly done the work through the drought. More work was afterwards added, and this same pair of engines without any farther change, indicated 536.87 horse power as shown in cards 1 and 2 C.

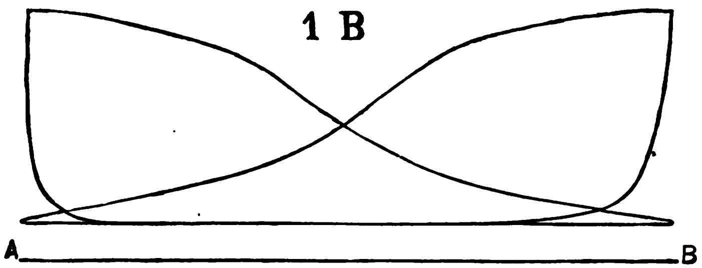


Steam, 77 lbs. Back pressure, 13 lbs. M. E. P., 43 lbs. I. H. P., 268.75. Less back pressure, 187.50.

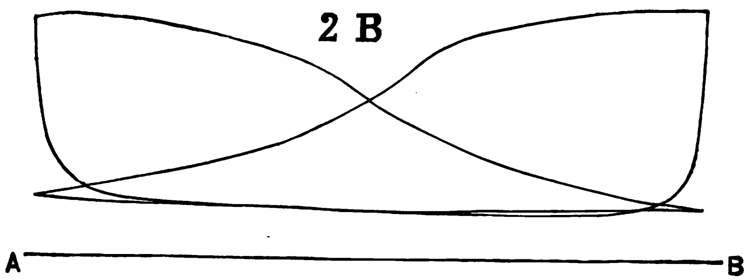


Steam, 78 lbs. Back pressure, 11.8 lbs. M. E. P., 42.9 lbs. I. H. P., 268.12. Less back pressure 194.37.

There are two important points shown in cards 1 and 2 C, and 1 and 2 B, all from the same engine: these are the great back pressure, and the falling off of pressure on the steam line previous to cut-off due to *small pipes and ports*, not being more than one-half the area necessary, when



Steam, 78 lbs. Back pressure, 10 lbs. M. E. P., 38.2 lbs. I. H. P., 238.75. Less back pressure 176.25.

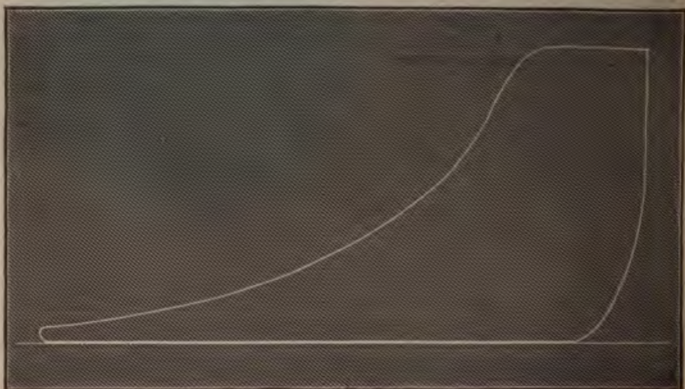


Steam, 76 lbs. Back pressure, 13 lbs. M. E. P., 41.6 lbs. I. H. P., 280. Less back pressure 178.75.

working at the power and speed indicated. Figure 2 C, shows 67 lbs. initial pressure; at point of cut-off the pressure is but 55 lbs., while the gauge within a short distance in main pipe indicated 78 lbs., showing the great loss of pressure by having pipes and steam ports so much out of proportion to size of cylinder. Again in diagram 1 C, the back pressure is 13 lbs., while the pressure in the main exhaust pipe was only 5 lbs. (the exhaust steam being used at that pressure for dyeing and heating), showing the enormous expenditure of steam and power. It is due to the Wheelock engine to say that this engine is very different from the "*Improved Wheelock*" of to-day, which in point of economy and uniform speed will compare quite favorably with any other.

By permission of Hill, Clarke & Co., Boston, several diagrams of the Hartford engines are given for the purpose of showing the workings of the engines under different loads and conditions. They are all 20x30 inch cylinder engine, running 130 revolutions per minute.
of the Cummer engine with description.

Fig. 6.



MINIMUM ECONOMICAL LOAD.

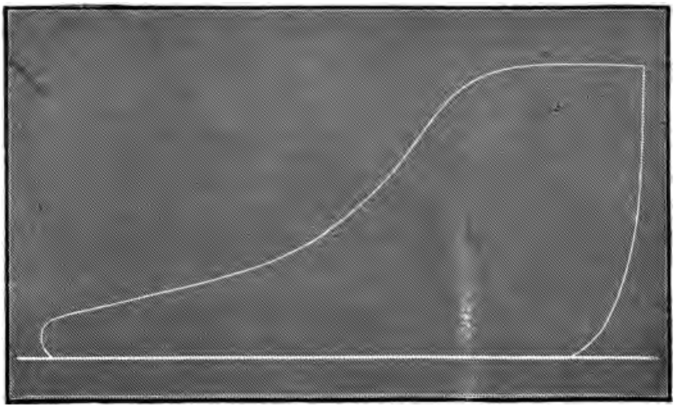
DATA.

Scale, 50. Mean effective pressure, 32. Terminal, 18.7. Steam per h. p. per hour, 18.8 lbs
Horse power, 199.56.

The best practice of the present day demands a mean effective pressure of about 40 pounds for the best actual economy, and builders endeavor to adapt their engines as nearly as possible to that pressure.

While the principle of condensation has been generally adopted with large mill engines (except in cases where the exhaust steam can be used to better advantage for boiling, drying and heating), there are many places where the independent condenser can be used with a saving of fuel of 25 to 35 per cent. The motion is very smooth and easy, and can be varied by the engineer to suit the requirements of water, engine duty, etc. The cost of running is very light, as the pump runs mainly on its own vacuum. The quantity of water required for condensation is about twenty-five times the feed water for the boiler. This form of condenser is much safer, *as the vacuum* can be got up, and pipe and steam chest cleared of water

Fig. 7.



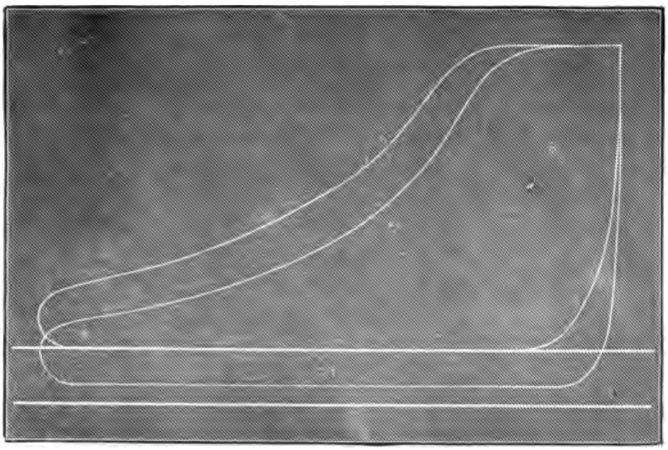
BEST ECONOMICAL LOAD.

DATA.

Scale, 50. **Mean effective pressure, 41.11. Terminal, 24. Steam per h. p. per hour,** 19.8 lbs. Horse power. 254.30.

before the engine is started. A very high vacuum can be got if desired, as shown in Fig. 8.

Fig. 8.



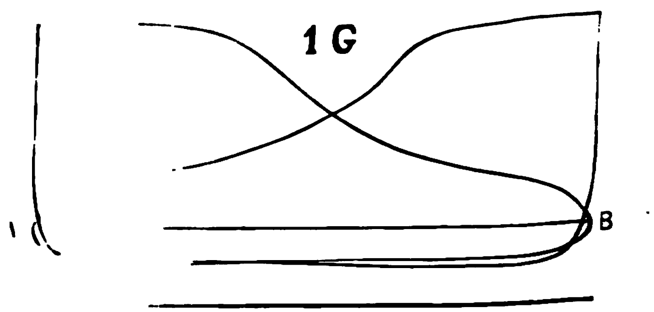
DATA.

Scale 50.		**Steam per h.p. per hour, high pressure,**	**19.6**
Mean effective pressure of both high and low pressure,	47.5	" " " " " low "	14.5
Terminal high pressure,	28.5	Indicated horse power,	290.
" *low pressure,*	19.6	Economy due to condensing,	35 per ct.

[illegible]

The following diag[illegible] inches, [illegible] revolutions per minute, having an independent condenser.

Note. "All the diagrams [illegible] scale, except two the scale of which [illegible]ed."

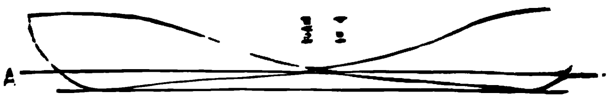


Steam, [illegible] lbs. Vacuum, 27 in. M. E. P., 41.4. I. H. P., 232.25.

Figure 1 G, shows the effect of the condenser with high steam and vacuum, working 232.25 horse power.

Steam, [illegible]

Figure 2 G, [illegible]

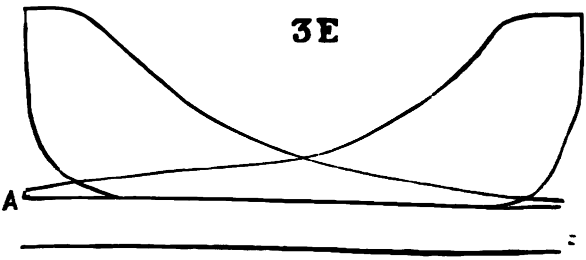


Steam, [illegible] lbs. [illegible]

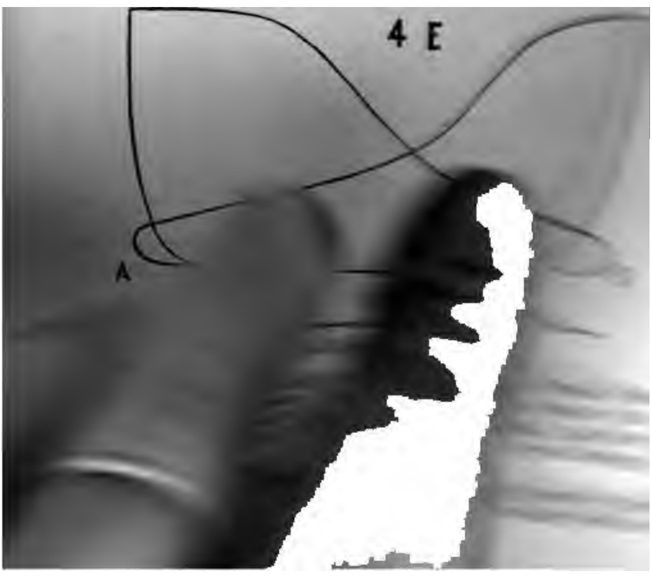
Figure 3 G. low steam [illegible] horse power.

The three diagrams were taken within a few minutes of each other from the same engine, and the [illegible] were made for the purpose of ascertaining the power required [illegible] shafting alone; the ordinary work and about half of the electric lights and shafting, and the addition of the balance of electric lights. Fig. 3 G showing the whole.

Figures 3 and 4 E. are from the same engine working high pressure under different loads. Figure 3 E shows the ordinary work, and Fig. 4 E. the addition of electric lights.



Steam, 55 lbs. M. E. P., 18 lbs. I. H. P., 100.9 [illegible]



proportion to the perfection of the vacuum. Atmospheric pressure, such as non-condensing engines work against, amounts to 14.7 lbs. per square inch. From 11 to 13 lbs. of this may be removed by means of a condenser, and is just so much added to the mean effective pressure, without any additional cost, except the small amount of power required to operate the air pump, as heretofore stated. Since a condenser will thus add so largely to the power and economy of the engine with but slight additional outlay, its use is recommended wherever a sufficient supply of good water can be obtained for injection, or where exhaust steam is not required for boiling and heating. As much of the discharge water from the condenser as may be required for feed, can be used, as the temperature would be about 110° F. In cases where a large amount of power is steadily required, the compound condensing engine is strongly recommended. Have the steam cylinders provided with casing for live steam, which makes the most efficient jacket known. Engines arranged with all the improvements specified in this work, have been known to work with the small amount of 1⅝ lbs. of coal per horse power per hour.

TABLE.

To determine mean pressure in the cylinder, when cutting off at points as below stated.

¼	Stroke	=	boiler	pressure	× by	.597
⅓	"	=	"	"	× "	.670
⅜	"	=	"	"	× "	.743
½	"	=	"	"	× "	.847
⅝	"	=	"	"	× "	.919
⅔	"	=	"	"	× "	.937
¾	"	=	"	"	× "	.966
⅞	"	=	"	"	× "	.992

TABLE.

To facilitate the measurement of diagrams, etc., or making other calculations, the following table of fractions of an inch, reduced to decimals will be found convenient:—

Com. Frac.	Decimal.	Com. Frac.	Decimal.	Com. Frac.	Decimal.	Com. Frac.	Decimal.
1/32	.0312	9/32	.2812	17/32	.5312	25/32	.7812
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
3/32	.0937	11/32	.3437	19/32	.5977	27/32	.8437
1/8	.1250	3/8	.3750	5/8	.6250	7/8	.8750
5/32	.1562	13/32	.4062	21/32	.6562	29/32	.9062
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
7/32	.2187	15/32	.4687	23/32	.7187	31/32	.9687
1/4	*.2500*	1/2	.5000	3/4	.7500	32/32	1.0000

TABLE.

Showing the elastic force, temperature, and volume of steam, at temperatures from 32° to 387.3° Fahrenheit, varying by 5° of temperature up to the boiling point, then by ½ lbs. of pressure on the square inch up to 25 lbs., then by lbs. of pressure up to 85 lbs., and then by 5 lbs. of pressure up to 200 lbs.

Elastic force in		Temperature.	Volume.	Elastic force in		Temperature.	Volume.
Inches of Merc'y.	Lbs. per Sq. inch.			Inches of Merc'y.	Lbs. per Sq. inch.		
.200	.098	32.	187407	31.62	15.5	214.5	1618
.221	.108	35.	170267	32.64	16.	216.3	1573
.263	.129	40.	144529	33.66	16.5	218.	1530
.316	.155	45.	121483	34.68	17.	219.6	1488
.375	.184	50.	103350	35.7	17.5	221.2	1440
.443	.217	55.	88388	36.72	18.	222.7	1411
.524	.257	60.	75421	37.74	18.5	224.2	1377
.616	.302	65.	64762	38.76	19.	225.6	1343
.721	.353	70.	55862	39.78	19.5	227.1	1312
.851	.417	75.	47771	40.80	20.	228.5	1281
1.	.49	80.	41031	41.82	20.5	229.9	1253
1.17	.573	85.	35393	42.84	21.	231.2	1225
1.36	.666	90.	30425	43.86	21.5	232.5	1199
1.58	.774	95.	26686	44.88	22.	233.8	1174
1.86	.911	100.	22873	45.90	22.5	235.1	1150
2.04	1.	103.	20958	46.92	23.	236.3	1127
2.18	1.068	105.	19693	47.94	23.5	237.5	1105
2.53	1.240	110.	16667	48.96	24.	238.7	1084
2.92	1.431	115.	14942	49.98	24.5	239.9	1064
3.33	1.632	120.	13215	51.	25.	241.	1044
3.79	1.857	125.	11723	53.04	26.	243.3	1007
4.34	2.129	130.	10328	55.08	27.	245.5	973
5.00	2.450	135.	9036	57.12	28.	247.6	941
5.74	2.813	140.	7938	59.16	29.	249.6	911
6.53	3.100	145.	7040	61.2	30.	251.6	883
7.42	3.636	150.	6243	63.24	31.	253 6	857
8.40	4.116	155.	5559	65.28	32.	255.5	833
9.46	4.635	160.	4976	67.32	33.	257.3	810
10.68	5.23	165.	4443	69.36	34.	259.1	788
12.13	5.94	170.	3943	71.4	35.	260.9	767
13.62	6.67	175.	3538	73.44	36.	262.6	748
15.15	7.42	180.	3208	75.48	37.	264.3	729
17.	8.33	185.	2879	77.52	38.	265.9	712
19.	9.31	190.	2595	79.56	39.	267.5	695
21.22	10.4	195.	2342	81.6	40.	269.1	679
23.64	11.58	200.	2118	83.64	41.	270.6	664
26.13	12.8	205.	1932	85.68	42.	272.1	649
28.84	14.13	210.	1763	87.72	43.	273.6	635
29.41	14.41	211.	1730	89.76	44.	275.	622
30.	14.7	212.	1700	91.8	45.	276.4	610
30.6	15.	212.8	1669	93.84	46.	277.8	598

Elastic force in		Tempera-ture.	Volume.	Elastic force in		Tempera-ture.	Volume.
Inches of Merc'y.	Lbs. per Sq. inch.			Inches of Merc'y.	Lbs. per Sq. inch.		
95.88	47.	279.2	586	159.14	78.	314.	370
97.92	48.	280.5	575	161.18	79.	314.9	366
99.96	49.	281.9	564	163.22	80.	315.8	362
102.	50.	283.2	554	165.26	81.	316.7	358
104.04	51.	284.4	544	167.3	82.	317.6	354
106.08	52.	285.7	534	169.34	83.	318.4	350
108.12	53.	286.9	525	171.38	84.	319.3	346
110.16	54.	288.1	516	173.42	85.	320.1	342
112.2	55.	289.3	508	183.62	90.	324.3	325
114.24	56.	290.5	500	193.82	95.	328.2	310
116.28	57.	291.7	492	203.99	100.	332.	295
118.32	58.	292.9	484	214.19	105.	335.8	282
120.36	59.	294.2	477	224.39	110.	339.2	271
122.4	60.	295.6	470	234.59	115.	342.7	259
124.44	61.	296.9	463	244.79	120.	345.8	251
126.48	62.	298.1	456	254.99	125.	349.1	240
128.52	63.	299.2	449	265.19	130.	352.1	233
130.56	64.	300.3	443	275.39	135.	355.	224
132.6	65.	301.3	437	285.59	140.	357.9	218
134.64	66.	302.4	431	295.79	145.	360.6	210
136.68	67.	303.4	425	306.	150.	363.4	205
138.72	68.	304.4	419	316.19	155.	366.	198
140.76	69.	305.4	414	326.39	160.	368.7	193
142.8	70.	306.4	408	336.59	165.	371.1	187
144.84	71.	307.4	403	346.79	170.	373.6	183
146.88	72.	308.4	398	357.	175.	376.	178
148.92	73.	309.3	393	367.2	180.	378.4	174
150.96	74.	310.3	388	377.1	185.	380.6	169
153.02	75.	311.2	383	387.6	190.	382.9	166
155.06	76.	312.2	379	397.8	195.	384.7	161
157.1	77.	313.1	374	408.	200.	387.3	158

HYPERBOLIC LOGARITHMS.

To Find the Mean Pressure by Hyperbolic Logarithms.

RULE.—Divide the length of the stroke by the length of the space into which the steam is admitted; find in the table the logarithm of the number nearest to that of the quotient, to which add 1. The sum is the ratio of the gain.

EXAMPLE.—Suppose the steam to enter the cylinder at the pressure of 40 lbs. per square inch, and to be cut off at $\frac{1}{4}$ of the length of the stroke; what is the mean pressure, the stroke being 10 feet?

10÷2.5=4. Hyp. log. of 4=1.38629+1=2.38629.

Then, as 4 : 2.38629 : : 40 : 23.8629 lbs.

TABLE

Of Hyperbolic Logarithms.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1.25	.22314	4.	1.38629	6.75	1.90954	12.	2.48490
1.5	.40546	4.25	1.44691	7.	1.94591	13.	2.56494
1.75	.55961	4.5	1.50507	7.25	1.98100	14.	2.63905
2.	.69314	4.75	1.55814	7.5	2.01490	15.	2.70805
2.25	.81093	5.	1.60943	7.75	2.04769	16.	2.77258
2.5	.91629	5.25	1.65822	8.	2.07944	17.	2.83321
2.75	1.01160	5.5	1.70474	8.5	2.14006	18.	2.89037
3.	1.09861	5.75	1.74919	9.	2.19722	19.	2.94443
3.25	1.17865	6.	1.79175	9.5	2.25129	20.	2.99573
3.5	1.25276	6.25	1.83258	10.	2.30258	21.	3.04452
3.75	1.32175	6.5	1.87180	11.	2.39789	22.	3.09104

TABLE

Of Steam Used Expansively.

Initial Pressure, lbs. per square inch.	Average Pressure of steam in pounds per square inch for the whole stroke.					
	Portion of stroke at which steam is cut off.					
	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
5	4.8	4.6	4.2	3.7	2.9	1.9
10	9.6	.9.1	8.4	7.4	5.9	3.8
15	14.4	13.7	12.7	11.1	8.9	5.7
20	19.2	18.3	16.9	14.8	11.9	7.6
25	24.1	22.9	21.1	18.5	14.9	9.5
30	28.9	27.5	25.4	22.2	17.9	11.5
35	33.8	32.1	29.6	25.9	20.8	13.4
40	37.5	36.7	33.8	29.6	23.8	15.4
45	43.4	41.3	38.1	33.3	26.8	17.3
50	48.2	45.9	42.3	37.0	29.8	19.2
60	57.8	55.1	50.7	44.5	35.7	23.1
70	67.4	64.3	59.2	52.4	41.7	26.9
80	77.1	73.5	67.7	59.3	47.7	30.8
90	86.7	82.6	76.1	66.7	53.6	34.6
100	96.3	91.8	84.6	74.1	59.6	38.4
110	106.0	101.0	93.1	81.5	65.6	42.5
120	115.2	110.2	101.5	89.4	71.5	46.1
130	125.4	119.1	110.0	95.3	77.5	50.0
140	134.9	128.6	118.5	103.8	83.3	53.8
150	144.7	137.8	126.4	111.2	89.4	57.7
160	153.6	147.0	135.4	118.2	95.4	61.5
180	173.5	164.6	152.3	132.9	107.3	69.2
200	192.7	183.7	169.3	148.3	119.3	76.9

TABLE

EXHIBITING THE EXPANSIVE FORCE AND VARIOUS CONDITIONS OF STEAM UNDER DIFFERENT DEGREES OF TEMPERATURE.

Degrees of heat.	Pressure in atmospheres.	Density. Water as 1.	Volume. Water as 1.	Spec. gravity. Air as 1.	Wgt. of a cubic ft. in grains.
212.	1	.00059	1694	.484	254
250.5	2	.00110	909	.915	483
276.	3	.00160	625	1.330	700
293.8	4	.00210	476	1.728	910
308.	5	.00258	387	2.120	1110
359.	10	.00492	203	3.970	2100
418.5	20	.00973	106	7.440	3940

[An atmosphere is 14 7-10 lbs. to the square inch.]

NOTE.—By the above table it is seen that any given quantity of steam having a temperature of 212° F., occupies a space, under the ordinary pressure of the atmosphere, 1694 times greater than it occupied when as water, in a natural state. It exerts a mechanical force, consequently, on a given surface, 1694 times greater than the weight or force of the atmosphere resting on the same surface—a force of 24902 lbs. on each square inch. A force, if we consider the volume as so many cubic inches, equal to the raising of 2087 lbs. twelve inches high, by a quantity of steam less than a cubic foot, heated only to the temperature of boiling water, and weighing but 248 grains, and that, too, the product of a single cubic inch of water!

The mean pressure of the atmosphere at the earth's surface, is equal to the weight of a column of mercury 26.9 inches in height, or to a column of water 33.87 feet in height,=2116.8 lbs. per square foot, or 14.7 lbs. per square inch. Its density above the earth is uniformly less as its altitude is greater, and its extent is not above 50 miles—its mean altitude is about 45 miles; at 44 miles it ceases to reflect light. Were it of uniform density throughout, and of that at the surface, its altitude would be but 5¼ miles. Its weight is to pure water of equal temperature and volume, as 1 to 829. It revolves with the earth, and its average humidity, at 40° of latitude, is 4 grains per cubic foot. Its weight at 60°, b. 30, compared with an equal bulk of pure water at 40°, b. 30, is as 1 to 830.1.

TABLE

OF THE DENSITY OF STEAM UNDER DIFFERENT PRESSURES.

Atmosphere.	Density.	Volume.	Atmosphere.	Density.	Volume.	Atmosphere.	Density.	Volume.
1	.00059	1694	5	.00258	387	12	.00581	172
2	.00110	909	6	.00306	326	14	.00670	149
3	.00160	625	8	.00399	250	16	.00760	131
4	.00210	476	10	.00492	203	18	.00849	117

The volumes are not direct, in consequence of the increase of heat.

COMPUTATION TABLE.

[*See Page 62.*]

P	W	P	W	P	W	P	W	P	W	P	W
3	39.10	23	34.70	43	33.42	63	32.70	83	32.18	103	31.77
4	38.47	24	34.61	44	33.38	64	32.67	84	32.16	104	31.75
5	37.95	25	34.53	45	33.34	65	32.64	85	32.14	105	31.73
6	37.54	26	34.45	46	33·30	66	32.61	86	32.12	106	31.71
7	37.22	27	34.37	47	33.26	67	32.58	87	32.09	107	31.69
8	36.93	28	34.29	48	33.22	68	32.55	88	32.07	108	31.67
9	36.67	29	34.22	49	33.18	69	32.52	89	32.05	109	31.65
10	36.44	30	34.15	50	33.14	70	32.49	90	32.03	110	31.63
11	36.24	31	34.08	51	33.10	71	32.46	91	32.00	111	31.61
12	36.06	32	34.01	52	33.06	72	32 43	92	31.98	112	31.59
13	35.89	33	33.95	53	33.02	73	32.40	93	31.96	113	31.57
14	35.73	34	33.89	54	32.98	74	32.38	94	31 94	114	31.55
15	35.59	35	33.83	55	32.94	75	32.36	95	31.92	115	31.54
16	35.46	36	33.77	56	32.91	76	32.34	96	31.90	116	31.53
17	35.34	37	33.72	57	32.88	77	32.32	97	31.88	117	31.52
18	35.22	38	33.67	58	32.85	78	32.30	98	31.86	118	31.51
19	35.10	39	33.62	59	32.82	79	32.27	99	31.84	119	31.50
20	34.99	40	33.57	60	32.79	80	32.25	100	31.82	120	31.49
21	34.89	41	33.52	61	32.76	81	32.23	101	31.80	121	31.48
22	34.79	42	33.47	62	32.73	82	32.20	102	31.78		

CISTERNS.

CAPACITY OF CISTERNS IN U. S. GALLONS, FOR EACH 10 INCHES IN DEPTH.

2	feet diameter	19.5	8	feet diameter	313.33
2½	"	30.6	8½	"	353.72
3	"	44.06	9	"	396.56
3½	"	59.97	9½	"	461.40
4	"	78.33	10	"	489.20
4½	"	99.14	11	"	592 40
5	"	122.40	12	"	705.
5½	"	148.10	13	"	827.4
6	"	176.25	14	"	959.6
6½	"	206.85	15	"	1101.6
7	"	239.88	20	"	1958.4
7½	"	275.40	25	"	3059.9

HORSES.

The following information in relation to horses will be found useful in reference to the application of steam:—

A *horse* travels 400 yards, at a walk, in 4½ minutes; at a trot, in 2 minutes; at a gallop, in 1 minute.

Average weight=1000 lbs. each.

A *horse* carrying a soldier and his equipments (say 225 lbs.), travels 25 miles in a day (8 hours).

A *draught horse* can draw 1600 lbs. 23 miles a day, weight of carriage included.

The ordinary work of a horse may be stated at 22.500 lbs., raised 1 foot in a minute, for 8 hours a day.

In a *horse mill*, a horse moves at the rate of 3 feet in a second. The diameter of the track should not be less than 25 feet.

A *horse power* in machinery is estimated at 33.000 lbs., raised 1 foot in a minute; but as a horse can exert that force but 6 hours a day, one machinery horse power is equivalent to that of 4.4 horses.

The *strength of a horse* is equivalent to that of five men.

TABLE

OF MEAN EFFECTIVE AND TERMINAL PRESSURES.

PRESSURES. Above Atmos.	PRESSURES. Above Vac'um	Point of Cut-Off.	Rate of Expan.	Mean pressure through't Stroke.	Back Pressure Non-Cond'g.	Back Pressure Cond'-ing.	M. E. P. Non-Cond's'g.	M. E. P. Condens-ing.	Terminal pressure above Vacuum.
50	65	$\frac{1}{5}$	5	33.77	16	4	17.77	29.77	12.94
		$\frac{1}{4}$	4	38.56	16	4	22.56	34.56	16.18
		$\frac{3}{8}$	2.66	48.14	16	4	32.14	44.14	24.26
		$\frac{1}{2}$	2	54.74	16	4	38.74	50 74	32.35
55	70	$\frac{1}{5}$	5	36.38	16	4	20 38	32.38	13.94
		$\frac{1}{4}$	4	41.54	16	4	25.54	37.54	17.43
		$\frac{3}{8}$	2.66	51.86	16	4	35.86	47.86	26.14
		$\frac{1}{2}$	2	58.97	16	4	42.97	54.97	34.85
60	75	$\frac{1}{5}$	5	38.99	16	4	22.99	34 99	14.94
		$\frac{1}{4}$	4	44.52	16	4	28.52	40.52	18.68
		$\frac{3}{8}$	2.66	55.58	16	4	39.58	51.58	28.01
		$\frac{1}{2}$	2	63.20	16	4	47.20	59.20	37.35
65	80	$\frac{1}{5}$	5	41.60	16	4	25.60	37.60	15.94
		$\frac{1}{4}$	4	47.50	16	4	31.50	43.50	19.93
		$\frac{3}{8}$	2.66	59.30	16	4	43.30	55.30	29.89
		$\frac{1}{2}$	2	67.43	16	4	51.43	63.43	39.85
70	85	$\frac{1}{5}$	5	44.21	16	4	28.21	40.21	16.94
		$\frac{1}{4}$	4	50.48	16	4	34.48	46.48	21.18
		$\frac{3}{8}$	2.66	63.02	16	4	47.02	59.02	31.76
		$\frac{1}{2}$	2	71.66	16	4	55.66	67.66	42.35
75	90	$\frac{1}{5}$	5	46.82	16	4	30.82	42.82	17.94
		$\frac{1}{4}$	4	53.46	16	4	37.46	49.46	22.43
		$\frac{3}{8}$	2.66	66.74	16	4	50.74	62.74	33.64
		$\frac{1}{2}$	2	75.89	16	4	59.89	71.89	44.85
80	95	$\frac{1}{5}$	5	49.43	16	4	33.43	45.43	18.94
		$\frac{1}{4}$	4	56.44	16	4	40.44	52.44	23.68
		$\frac{3}{8}$	2.66	70.46	16	4	54.46	66.46	35.51
		$\frac{1}{2}$	2	80.12	16	4	64.12	76.12	47.35
85	100	$\frac{1}{5}$	5	52.04	16	4	36.04	48.04	19.94
		$\frac{1}{4}$	4	59.42	16	4	43.42	55.42	24.93
		$\frac{3}{8}$	2.66	74.18	16	4	58.18	70.18	37.39
		$\frac{1}{2}$	2	84.35	16	4	68.35	80.35	49.85
90	105	$\frac{1}{5}$	5	54.65	16	4	38 65	50.65	20.94
		$\frac{1}{4}$	4	62.40	16	4	46.40	58.40	26.18
		$\frac{3}{8}$	2.66	77.90	16	4	61.90	73.90	39.26
		$\frac{1}{2}$	2	88.58	16	4	72.58	84.58	52.35
95	110	$\frac{1}{5}$	5	57.26	16	4	41.26	53.26	21.94
		$\frac{1}{4}$	4	65 38	16	4	49.38	61.38	27.43
		$\frac{3}{8}$	2.66	81.62	16	4	65.62	77.62	41.14
		$\frac{1}{2}$	2	92.81	16	4	76.81	88 81	54 85
100	115	$\frac{1}{5}$	5	59.87	16	4	43 87	55.87	22.94
		$\frac{1}{4}$	4	68.36	16	4	52.36	64.36	28.68
		$\frac{3}{8}$	2.66	85.34	16	4	69.34	81.34	43.01
		$\frac{1}{2}$	2	97.04	16	4	81.04	93.04	57.35

NOTE.—In order to get rid of an inconvenient fraction in the second column, the pressures above the atmospheric are given in round numbers at 15 lbs. instead of 14.7 lbs. The calculations are all made with the latter and not the former figures.—Cummer Engine Co.

INSPECTION OF STEAM BOILERS, AND EXAMINATIONS OF ENGINEERS AND FIREMEN.

From a careful examination of the recent law, as passed by the Massachusetts Legislature, on this subject, it will be found that engineers and firemen will be required to have an examination by one of the inspectors.

It will therefore be necessary for such as make application for a license to be familiar with the details of what may be required of them at that examination.

For the purpose of giving those interested a better conception of what might be required, the author has formulated a series of questions and answers bearing upon the subject, the substance of which will probably be used in conducting the examinations.

In presenting this little book, it is not claimed that it is entirely new. Much has been selected from standard authorities, such as "Haswell," "Briggs" and "Williams," for which thanks are here presented, and due acknowledgement herein made. He has also reproduced considerable published in a former work of his own, bearing upon the subject, which may be found helpful.

The book is submitted, trusting that it may reach the large class it is designed to benefit.

A copy of the law is here inserted:

CHAPTER 471, ACTS OF 1895.

AN ACT TO REGULATE STEAM ENGINEERING.

Be it enacted, etc., as follows:

SECTION 1. It shall be unlawful for any person to have charge of or to operate a steam boiler or engine in this Commonwealth, except locomotive boilers and engines, boilers in private residences, boilers under the jurisdiction of the United States, and boilers used for agricultural purposes exclusively or of less than eight horse power, unless he holds a license as hereinafter provided; and it shall be unlawful for any owner or user of any steam boiler or engine, other than those above excepted, to operate or cause to be operated a steam boiler or engine for a period of more than one week without a duly licensed engineer or fireman in charge.

SECTION 2. Any person desiring to act as an engineer or fireman shall make application to so act to an examiner of engineers, upon blanks furnished by the examiner, and if upon examination the applicant is found trustworthy and competent a license shall be granted to said applicant to have charge of or to operate such steam plants as the examiner may find him qualified to have in keeping. Such license shall continue in force for three years unless after proper hearing it is sooner revoked, for intoxication or other sufficient cause, and may be renewed every three years on application to the authority granting the same, or at such time as may be determined by said authority.

SECTION 3. Licenses shall be granted according to the competency of the applicant, and shall be divided into classes as follows:— First Class. Engineers' licenses of this class shall be unlimited as to horse power. Second Class. Engineers' licenses of this class shall be limited to one hundred and fifty horse power. Third Class. Engineers' licenses of this class shall be limited to fifty horse power. A fireman's license shall be issued to any person who, after having passed an examination, as herein provided, shall have been found competent to take charge of or to operate any steam boiler or boilers. Any person desiring to operate any particular steam plant may so state to the

examiner, and he shall be examined as to his fitness to operate that particular plant, and if found competent and trustworthy shall be granted a license, termed a special license, for that particular plant, and such license shall be in force for three years.

SECTION 4. The fee for examination for applicants for license shall be one dollar, to be paid at the time of the application for examination, and one dollar for each renewal of license. All sums paid as aforesaid shall be received by the examiner, and shall be paid over by him monthly to the treasurer of the Commonwealth if such examiner is a member of the district police, otherwise to the treasurer of the town or city by which such examiner is employed.

SECTION 5. The members of the boiler inspection department of the district police shall act as examiners and enforce the provisions of this act.

SECTION 6. It shall be the duty of the examiners to notify every person operating a boiler or engine mentioned in section one and not included among the exceptions therein specified, to apply for a license under this act and to give such persons a reasonable opportunity to take an examination therefor within the town or city in which he is engaged in operating such boiler or engine. The examiner shall issue a license or shall notify the applicant of his rejection within forty-eight hours after his examination.

SECTION 7. Any person dissatisfied with the action of an examiner in refusing or in revoking a license may appeal to the chief of the district police, whose decision shall be final.

SECTION 8. Whoever, after being notified as provided in section six, intentionally violates the provisions of section one of this act shall be punished by fine not exceeding three hundred dollars or by imprisonment not exceeding three months.

SECTION 9. This act shall take effect on the first day of August in the year eighteen hundred and ninety-five, and any person applying for a license as engineer or fireman on or before that date shall be deemed to have complied with the provisions of this act until his application is passed upon or rejected by the proper authorities.

[*Approved June 5, 1895.*

CHAPTER 418, ACTS OF 1895.

AN ACT RELATIVE TO THE INSPECTION OF STEAM BOILERS.

Be it enacted, etc., as follows:

SECTION 1. It shall be the duty of every corporation, firm or individual, owning or using, or causing to be used, within this Commonwealth, a steam boiler or boilers (excepting boilers upon locomotives, boilers in private residences, boilers under the jurisdiction of the United States, boilers that are under the periodically guaranteed inspection of companies that have complied with all the laws of this Commonwealth, boilers used exclusively for agricultural, horticultural and creamery purposes, or boilers of less than three horse power), within sixty days after the passage of this act, and annually thereafter, to report to the chief of the district police the location of such steam boiler or boilers.

SECTION 2. Each of the boilers designated in section one shall be inspected by the inspector of boilers for the district in which said boiler or boilers is located, as thoroughly as in the judgment of the inspector is necessary, and if the inspector so directs, it shall be the duty of the owner or user to have the boiler or boilers blown off dry, and the man-hole and hand-hole covers thereon removed, ready for inspection upon the day designated by the inspector, the inspector giving the owner or user of said boiler or boilers four-

teen days' notice in writing of the day upon which he will make such internal inspection, provided that such inspection shall not be required oftener than twice a year.

SECTION 3. If upon examination said inspector shall find the boiler inspected to be worthy and in safe working order, with the fittings necessary to safety, and properly set up, he shall grant to the owner or user of such boiler or boilers a certificate of inspection, and upon receipt of such certificate said owner or user shall be permitted to use the boiler or boilers mentioned in the certificate. And if in said inspection the inspector shall find that the boiler is not in safe condition, or not provided with fittings necessary to safety, or with fittings not properly arranged, he shall withhold his certificate until the boiler and fittings are put in condition satisfactory to him; and it shall be unlawful for any owner or user to then operate or cause to be operated such steam boiler until the inspector has granted his certificate, and the owner or user operating such boiler without said certificate may be enjoined from such use, in a proceeding to be had before the superior court or the supreme judicial court, at the instance of the inspector, with the approval of the chief of the district police; and upon the filing of a petition therefor any judge or justice of the court in which said proceeding is pending may issue a temporary injunction or restraining order, as provided in proceedings in equity.

SECTION 4. If upon such inspection the inspector finds that the owner or user of any steam boiler is putting too much pressure upon the same the inspector shall have the power to fix the maximum pressure to be allowed to be carried by said boiler, and shall adopt, and the owner or user shall place or cause to be placed upon said boiler, such device as the inspector shall deem expedient to prevent the boiler from carrying any greater than the maximum pressure designated, said device to be approved by the chief of the district police; and no person shall in any manner tamper with such device, or load the safety valve to a greater pressure than that allowed by the inspector, as hereinbefore provided.

SECTION 5. The owner or user of a boiler or boilers coming under the provisions of this act shall pay to the inspector at each inspection the sum of two dollars for each boiler inspected. All sums paid as aforesaid shall be paid over by him, monthly, to the treasurer of the Commonwealth.

SECTION 6. The chief of the district police is hereby authorized to adopt such rules and regulations, to be approved by the governor, as may be necessary to properly enforce this act.

SECTION 7. All persons violating any of the provisions of this act shall, upon conviction, be punished by a fine not exceeding five hundred dollars, or by imprisonment not exceeding six months, or both, at the discretion of the court.

SECTION 8. The governor is hereby authorized to appoint three additional members to the inspection department of the district police qualified to perform the duties required by this act, who shall each receive an annual salary of fifteen hundred dollars and their actual travelling and necessary expenses.

SECTION 9. This act shall take effect upon its passage.

Approved May 29, 1895.

STEAM.

The following may comprise the basis of the questions asked:

1. What is steam?

A. Steam is an elastic vapor of several fluids; namely, —alcohol, benzine, naphtha and water: that of the latter only is usually known and recognized as steam.

2. What are its component parts?

A. The vapor from boiling water, called steam, chemically considered, contains eight parts, by weight, of oxygen and one part of hydrogen. Steam proper is perfectly transparent, colorless and dry; and moist only when condensed; visible only by partial condensation.

3. What is the weight of steam?

A. At the pressure of the atmosphere, 26.36 cubic feet weighs one pound (avordupois), or five cubic feet of steam at 75 lbs. pressure per square inch weighs about one pound.

4. What is meant by low pressure steam?

A. Not exceeding 15 lbs. per square inch.

5. What is meant by super-heated steam?

A. Steam that has a greater temperature than that due to its pressure. That is, heat is applied to the steam-pipes or vessel containing steam after it has left the water from which it was generated.

6. Does the pressure of steam increase as fast as the temperature?

A. The pressure of steam increases at a far higher rate than the temperature; doubling the temperature increases the pressure nearly twenty-three times.

7. How do we find the latent heat of steam?

A. The latent heat of steam is generally found by subtracting its sensible heat from 1202. At 45 lbs. it will be exactly right, for at that pressure the total heat will be just 1202^0 Fahr.

8. Does steam or vapor rise from water at all temperatures?

A. It does.

9. Is there any difference between steam and vapor?

A. The chemical analysis shows no difference, but the different authorities generally consider them different; for usually speaking steam is formed artificially, while vapor is formed naturally; and another difference is the temperature. Anything less than 212^0 Fahr. is styled vapor (really steam), and over that it would be *called* steam.

10. Are there any rules for the amount of steam-pipe required to heat a building with steam?

A. "*The Master Steam Fitter*" gives three rules as follows, but the third one is considered the most practicable. 1. One square foot of steam-pipe for every six square feet of glass in the windows. 2. One square foot of steam-pipe for every 100 square feet of wall and ceiling. 3. One square foot of steam-pipe for every 80 cubic feet of space to be heated. These rules would be applicable to Boston and vicinity; for Portland, Me., add 20 per cent. more; for New York, 20 per cent. less.

11. Suppose we have 6 stores to heat with steam; dimensions of each as follows: 90 feet long, 30 feet wide, 12 feet high. How many square feet of 1-inch pipe will be required to heat them, the pipe being about 4 inches in circumference? How many running feet would be required?

A. Example. Rule 3.

90	feet, length of each store.
30	" width " " "
2700	square feet.
12	feet, height of each store.
32400	cubic feet of space in 1 store.
6	
194400	cubic feet of space in 6 stores.

Divide the cubic feet of space by 80, which is the number of square feet that 1 square foot of steam-pipe will heat.

```
80 ) 194400 ( 2430 square feet.
     160
     ---
      344
      320
      ---
       240
       240
       ---
         0
```

3 running feet of 1-inch pipe is required to heat 1 square foot of space, therefore

```
2430 square feet.
   3
----
7290 number of running feet required.
```

12. How does steam absorb what is called "latent" heat?

A. When steam is generated in a boiler, the water is heated until it arrives at the boiling point (212° Fahr.) and if the vessel is open the temperature cannot be raised any higher. But if we wish to convert all the water into steam we will need to add a great deal more heat. This is the heat that disappears, or latent heat, as it is called; for the steam rising from boiling water in an open vessel is of the same temperature as the water, sensibly, but still we know it contains a great deal more heat than the water (sensible and latent heat combined).

13. How much lighter is steam at 212° Fahr. than air?

A. Steam at 212° Fahr. is not quite one-half as heavy as air, the specific gravity of air being 1.0000, and that of steam at 212° Fahr. but .4883.

14. In running an engine, which is the more economical, high or low pressure steam?

A. High pressure steam is the most economical, because we have the advantage of a greater expansive force.

15. In heating a building, which is the more economical, high or low pressure steam?

A. Low pressure, for the relative volume of steam decreases faster than the temperature increases as the pressure rises.

16. What is meant by the relative volume of steam?

A. It is the proportional amount of steam that a certain amount of water will produce.

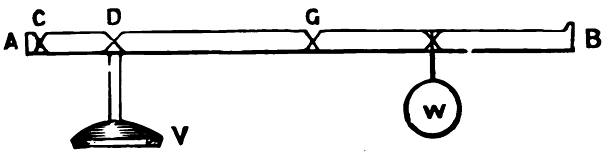
17. Give a table of the relative volume of steam at different pressures; also the temperatures.

A. Steam.	Temperature in Fahr.	Relative Volume.
10 lbs. per square inch	212°	1700
15 " " " "	240°	1040
20 " " " "	250°	903
25 " " " "	260°	765
30 " " " "	267°	677
35 " " " "	274°	608
40 " " " "	281°	552
45 " " " "	287°	506
50 " " " "	293°	467
55 " " " "	298°	434
60 " " " "	303°	406

Steam.	Temperature in Fahr.	Relative Volume.
65 lbs. per square inch.	308°	381
70 " " " "	312°	359
75 " " " "	316°	340
80 " " " "	320°	323
85 " " " "	324°	307
90 " " " "	328°	293
95 " " " "	332°	281
100 " " " "	335°	269
105 " " " "	338°	259
110 " " " "	341°	249
115 " " " "	344°	239
120 " " " "	347°	231
125 " " " "	350°	223
130 " " " "	353°	216
135 " " " "	356°	209
140 " " " "	358°	203
145 " " " "	360°	197
150 " " " "	363°	191
155 " " " "	365°	186

NOTE. By permission, the above series of questions and answers in relation to steam were taken from "*Key to Engineering*," by Henry S. Williams.

18. How would you set a safety valve if there was no gauge on the boiler?



EXPLANATION OF CUT.

Let A-B represent lever; C, fulcrum; D, point of application of the power of the steam tending to raise the valve, V; G, the centre of gravity of the lever; W, the weight.

A. Referring to cut. Multiply the area of valve by pressure of steam per square inch; subtract weight of valve; multiply the remainder by length of fulcrum; subtract weight of lever from that product (which would be the distance from the centre of gravity of the lever in inches to the outer end. The centre of gravity of the lever is obtained by balancing the lever over a knife-edge and marking it, or if the lever bar is parallel, measure from the centre to the end in inches to get the centre of gravity); multiply this length by weight of lever, and subtract the amount from the product, as above stated; divide the remainder by the weight of ball, and the quotient gives its position on the lever to produce the required pressure. If you desire the ball placed at the end of the lever, divide the remainder as above by the whole length of the lever in inches and the quotient will be the required weight of the ball.

EXAMPLE. Suppose the lever be 40 inches long, the fulcrum 5 inches, the centre of gravity of lever be 20 inches, the diameter of valve be 4 inches, and the weight be 80 lbs., where shall the weight be placed upon the lever; *i. e., at what distance* from the fulcrum, in order that 50 lbs. pressure per

square inch may be kept upon the valve, supposing that the valve itself weighs 5 lbs.

Area of valve, . . .	12.57	
Multiply by pressure, . .	50	
	628.50	
Subtract weight of valve, .	5	lbs.
	623.50	
Multiply by fulcrum, . .	5	inches.
	3,117.50	lbs.

The lever weighs 10 lbs., multiplied by leverage, 20 inches, makes 200 lbs., to be subtracted from 3117.5 lbs.

200 "

divided by weight 80) 2917.5 (36.47 inches, the distance the weight is placed from the fulcrum.

```
240
---
517
480
---
 375
 320
 ---
  550
  480
  ---
   70
```

Or, if you desire the ball to be placed at the end of the lever, divide the remainder, as above, by the length of the lever from the fulcrum, thus:

40) 2917.5 (72.9 the weight of the ball.

```
280
---
117
 80
---
 375
 360
 ---
  15
```

19. How would you find the required area of safety valve to the square foot of grate surface?

A. Allow half of square inch of area of safety valve to each square foot of grate surface. (G. S.)

20. What should be the distance of G. S. to boiler?

A. About 24 to 30 inches in the centre, according to the fuel used.

21. What should be the distance from the bridge wall to the boiler?

A. About 12 inches in the centre, or 18 square inches of space per H. P.

22. What should be the area of G. S. to an 80 H. P. boiler?

A. 40 square feet, or one-half of a square foot to a H. P.

23. What amount of coal can be burned with economy to the square foot of G. S.?

A. 10 lbs. would be considered good economy.

A. Rule 1. Multiply square of thickness by constant number 89600; divide the result by length in feet and diameter in inches.

```
                                   89600 constant.
                                     .25 square of thickness.
 40 inches diameter.               ------
  4 feet length to ring.          448000
 ---                              179200
 160                              ------
                             160 ) 22400.00 ( 140 lbs.
                                   160
                                   ---
                                   640
                                   640
```

31. What is the actual collapsing pressure of the above flue?

A. Multiply square of thickness by constant number 806300, and divide by length in feet and diameter in inches.

```
A. Rule 2. Constant number      806300
                                   .25
                               -------
                               4031500
                              1612600
                              --------
divide by length and diameter, 320 ) 201575.00 ( 629.92 lbs. collapsing pressure
                                   1920
                                   ----
                                    957
                                    640
                                    ----
                                    3175
                                    2880
                                    ----
                                     2950
                                     2880
                                     ----
                                       700
                                       640
                                       ---
                                        60
```

32. What would you do if the safety plug should blow out?

A. If the boiler was an upright or locomotive style with the safety plug in the crown sheet, where it would be accessible from the fire box, the fire should be drawn and cool down the fire box as quickly as possible. If the engine were running, or steam being drawn from the boiler, continue to do so; when cooled sufficiently, get into the fire box and put in a new plug; if water could be pumped in with safety, do so. If the boiler was a return flue or tubular form, and access could be had at the rear end by means of a door or arch, the fires might be covered with ashes. Work the steam down by opening the fire doors; cool down as soon as possible, as in the other case; if necessary, draw the fires and put in a new plug as soon as it could be done.

33. What is boiler efficiency?

A. When a boiler or boilers are of sufficient size, proper construction, and can do the required duty without overcrowding, they might be deemed efficient.

34. What would you do to avoid leaky seams and tubes?

A. Keep the boilers clean by a regular system of blowing off every day

when the steam is partially down and the water is quiet; before starting the engine in the morning is the best time. Avoid using too much kerosene or soda ash, particularly the former, as it is liable to produce leaks. When the water is bad and forms scale, something has to be done; find out the nature of the scale by analysis or experiment, and use that which proves best.

35. Which will stand the most pressure, a large boiler or a small one?

A. A small boiler with same thickness of material.

36. Where should the feed pipe enter the boiler; and is it a good plan to blow off and feed through the same pipe?

A. The feed pipe should enter near the top above the water line in the form of a spray, that it may the more readily and equally circulate; it is not a good plan to blow off and feed through the same pipe.

37. Which will carry the water better, a two-inch pipe, or four one-inch pipes under equal pressure?

A. The two-inch pipe takes the preference for the reason that it has only half the friction surface, and is carried more readily in one large current rather than in four small independent ones.

38. If the pressure is one pound to the square inch to a column of water 2.36 inches high in a one-inch pipe, what would it be in a six-inch pipe?

A. One pound to the square inch.

39. At what temperature will fresh water boil at tide-water?

A. 212° Fahrenheit.

40. What is temperature of steam at 100 pounds pressure?

A. 332° Fahrenheit.

41. What is the meaning of saturated steam?

A. Steam that is more or less visible and dense, holding in suspension more or less water, while superheated or non-saturated steam has the character of gas or vapor.

42. At what height will a pump lift water at sea level; and will it lift hot water at the same height?

A. If the pump is in good condition it will lift water about 34 feet, or rather the pressure of the atmosphere will force the water up the pipe that height (it being 14.7 pounds per square inch). It will not force hot water up to the same height.

43. Explain the working of an ordinary steam gauge.

A. A steam gauge is made with a hollow bent flat brass spring in which the pressure is applied; to the end or ends is adjusted a lever, single or double, as the style of gauge requires, which acts upon a segment of a gear which works into a pinion that controls the movement of the dial hand. This dial hand can be adjusted at any time to suit a test pump and gauge that is known to be correct.

44. How would you set the valves of an ordinary slide-valve engine?

A. Place the engine on either centre with the eccentric loose upon the shaft, the eccentric straps sufficiently tight to turn free, the eccentric rod connected with the valve stem or rocker arm, if there be one, and that connected with the valve stem. The first operation is to square the eccentric, by revolving the eccentric upon the shaft, to ascertain if the eccentric rod and valve stem is the right length. If the rod is right, the rocker arm should be perpendicular when the eccentric is at half throw; if not right, make it so by means of the adjusting thread and check-nut on the rod. To adjust the valve stem, set the eccentric at the extreme throw, when the crank is at the head end centre. Set the valve about the required lap, by adjusting the length of the valve stem. Secure it by means of the check-nuts; revolve the eccentric on the shaft to the extreme throw at the other end. See if the laps are alike;

if not, divide the difference. Turn the eccentric (the crank being on the head end centre). See that the laps are about equal; if not, now is the time to correct it; if right, and you wish to run your engine over, advance your eccentric until you get the necessary lead on the steam port at the head end. If the engine is short stroke and high speed, it will require more lead than for a long stroke and slow speed. About $\frac{1}{32}$ of an inch is about right for high speed. Now secure the eccentric fast to the shaft. Turn the engine round to the other centre. Ascertain if the lead is right; it is well to have the head end a trifle the most lead if the engine has not a balanced crank disk.

45. How would you set the valves on a Corliss engine?

A. Square the wrist-plate by the same process as for a plain slide-valve engine. First get the centre of the hub; draw a perpendicular line equidistant between the two steam-valve rod centres and the two exhaust-valve rod centres, striking the centre of the wrist-plate hub. Set your valves, both steam and exhaust, by this same process, except that the wrist-plate is supposed to be in a perpendicular position in relation to the central line and be so fixed. When adjusting the valves, the lines of the ports should be marked plainly on the back end of the valve chamber, and lap of the valves marked on the back of the valves.

46. If the eccentric of a Corliss engine slipped when running, how would you set it with the least delay?

A. Have distinct marks upon the shaft, and corresponding marks upon the face of the eccentric that was made after the valves had been set by the indicator and the engine had been run sufficiently long with the load on to get into good condition; have also similar marks made upon the hub of the wrist-plate.

47. What changes would have to be made in a Corliss engine to run in the opposite direction from which it had been running?

A. Precisely the same as with any other engine. Set the engine on the centre, and advance the eccentric ahead of the crank in the direction required to run, sufficient to give the necessary lead, the valve rods being connected. The cut-off and drops might need some adjustment.

48. What is the eccentricity of the eccentric?

A. Twice the distance from the centre of the hole to the centre of the eccentric.

49. If required to convert a single-eccentric slide-valve rocker-arm engine into a reversible engine, how would you do it?

A. By adding another eccentric and setting them to run in opposite directions. Have each connected with opposite ends of a reversible link motion, having a sliding block controlled by a lever to use either end at will, the valve stem to be connected with the sliding block. Or a hook attached to each eccentric rod, to be controlled and thrown out at will by means of levers for the purpose. The first plan is considered the most satisfactory.

50. What is the difference between a simple and a compound engine?

A. A simple engine would have one cylinder only; it might be condensing or non-condensing. If two cylinders, with two cranks, a pair of such. If one of the cylinders was smaller than the other and used high pressure steam and exhausted into the other, it would be called a cross compound. If the cylinders were placed tandem, it would be a tandem compound. If a condenser was used in either case, it would be a condensing engine.

51. How many cylinders are there to a double tandem condensing, triple expansion engine?

A. Six.

52. How are they arranged?

A. Three at each end of the crank shaft.

53. How would you find the clearance of the piston without taking the heads off?

A. Place the engine on the back centre; mark the position of the cross head on the guides; take out one of the connecting rod keys, and push the piston back until it strikes the head; measure the clearance, then put in the key and turn the engine to the other centre; mark the cross head on the guides; take out the inside connecting rod box; pull back piston until it strikes the head; measure the clearance; make it equal by adding or taking out liners. Another way, which may be quicker in some cases: Put the engine on either centre, as most convenient to handle the connecting rod; mark the cross head as before; take off the rod, push back the piston, note the clearance, measure from mark on guide the length of stroke, mark the guide, push back the piston, note the clearance.

54. What is the average consumption of coal per H. P. per hour of simple engines; and what of compound engines?

A. Plain slide-valve engines would require from 4 to 5 lbs. per H. P. per hour, while simple automatic cut-off engines would not require more than 3 lbs. per H. P. per hour; a simple compound about $2\frac{1}{4}$ lbs. per H. P. per hour.

55. What is the advantage of compounding?

A. To get the full advantage of expansion combined with having all the benefit possible that can be derived from the use of the large or larger cylinders together with a condenser.

56. What is meant by vacuum?

A. The pressure of the atmosphere at the level of the sea is 14.7 lbs. By removing as much of this as possible from the area of the larger cylinder by the use of the condenser and air pump, we add practically so much to the working pressure on the other side of the piston.

57. What is a unit of heat; and what is latent heat?

A 1. It is an amount of heat required to raise 1 pound of water 1° Fahrenheit.

A 2. It is estimated that there are about 1004 Fahrenheit units of heat that disappear in the conversion of one pound of boiling water into steam, and yet the steam will only have the same amount of sensible heat as the water, for there is so much heat that disappears, or becomes latent, in changing water into steam. This is called latent heat.

58. What is the pressure of the atmosphere at the sea level?

A. 14.7 pounds.

59. What is an Indicator; and what is it for? Give a description of it.

A. An indicator is an instrument used on a steam-engine cylinder while in operation for the purpose of ascertaining accurately the position of the valves and of determining positively any imperfections in the working of the engine, any leaks in the piston or valves; in fact, to obtain an actual transcript of what is going on in the cylinder, and by means of a series of diagrams taken calculations can be made of the amount of work performed; and by carefully weighing the amount of coal consumed, and the waste of ash, the economical result can be obtained.

60. Give rule for finding the H. P. of an engine?

A. Multiply the area of the piston in square inches by twice the length of the stroke in feet, this product by the number of revolutions per minute. Divide the result by the standard of H. P. (33,000 lbs.) which gives the H. P. constant at one lb. pressure. Multiply this quotient by the mean effective pressure (M. E. P.) as taken by the indicator; gives the indicated horse power (I. H. P.).

61. What is the horse power constant of an engine?

A. It is the H. P. of the engine at one lb. pressure, obtained by the rule as given in last answer.

62. What is the mean effective pressure; and how do you get it?

A. It is the average pressure of the steam in the cylinder from the beginning to the end of the stroke; you get it by the use of the indicator and planimeter. If you do not have a planimeter, divide the card into ten equal divisions; measure the height of each division with a scale which corresponds to the spring of the indicator; take the measurement from the vacuum line to the steam line if a condensing engine, if non-condensing from the exhaust line to steam line; add all the measurements together and divide by 10. The result will be the mean effective pressure (M. E. P.). If the engine is working under a back pressure, measure from the atmospheric line to the exhaust line with the scale, which makes so much additional load.

63. What is the vacuum created in a pump?

A. Removal of the pressure of the atmosphere.

64. How do you line and set up an engine?

A. By drawing a line through the centre of the cylinder; have the cylinder and bed level, the guides in line with the centre of the cylinder, the shaft level and at right angles with the line. Prove it by revolving the shaft by means of the band wheel; ascertain that the line strikes the crank pin midway between the shoulders of the crank pin at the four extreme positions, vertical and horizontal.

65. How do you find the dead centre of the crank?

A. By setting it as nearly in line with the guides as possible, then carefully watching the marks on the guides, turning the engine slowly; some builders mark the crank disk (if there be one) with a punch mark, and also the bed, using a tram to designate when the crank centre comes round to the right position.

66. If the eccentric of an engine were worn out of round and turned up in a lathe by taking $\frac{1}{4}$ inch off, what change would it make in the travel of the valves?

A. It would make the eccentric rod as much shorter as the amount of metal taken off one side of the eccentric, including also what might be bored out of the strap to refit it. Practically it shortens the rod one-half of what the diameter and straps have been reduced. The rod would have to be lengthened to that extent. It would not affect the throw of the eccentric.

67. In a vertical engine should the steam valves have an equal amount of lead?

A. No; the bottom valves should have the most.

68. If the governor belt of a Corliss engine should break, what effect would it have on the engine?

A. Unless there should be an automatic stop on the governor to hold it up, the speed would increase very rapidly and produce damage unless some one was near at hand to close the throttle valve.

69. Can an injector take steam from a boiler having 50 lbs. pressure to the square inch force water into a boiler having 75 lbs. pressure?

A. No; and yes; in some particular cases, dependent upon the amount of vacuum produced, some injectors raise and force water. It would be the safer plan to take the steam from the boiler with the higher pressure.

70. What is a short rule to determine the area of a segment of a circle?

A. Multiply versed sine by two-thirds of chord; add 15 per cent.

71. What is the area of a segment of a tubular boiler head 60 inches long, 24 inches versed sine?

A. Example. Two-thirds of sixty equals 40
Multiply by . . . 24 versed sine.

```
     160
     80
    ----
     960 square inches.
add   15 per cent.
    ----
    4800
    960
   -----
   144.00
   960
   -----
Area 1104 square inches.
```

72. What number of 1-inch braces is required for the heads of above boiler, with steam at 90 lbs. pressure, factor of 6000?

A. Rule: multiply area by pressure and divide by factor 6000.

```
                Area 1104 square inches.
                      90 lbs. pressure.
                   -----
factor 6000 ) 99360 ( 16.5 say 17 braces.
              6000
              -----
              39360
              36000
              ------
               33600
               30000
               -----
                3600
```

73. What number of $\frac{7}{8}$-inch braces required for same heads and pressure, factor of 5250?

```
A. Factor 5250 ) 99360 ( 18.9 say 19 braces.
                 5250
                 -----
                 46860
                 42000
                 ------
                  48600
                  47250
                  ------
                   1350
```

INDICATOR PRACTICE.

The following diagrams, taken from the writer's practice, are very pointed and striking, a vast amount of information may be obtained from a careful examination of them in detail.

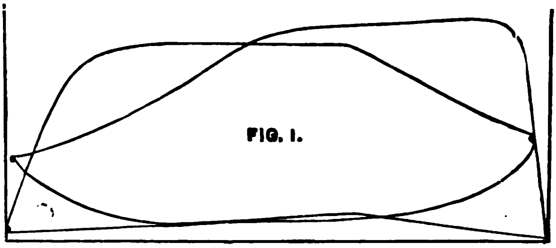


FIG. 1.

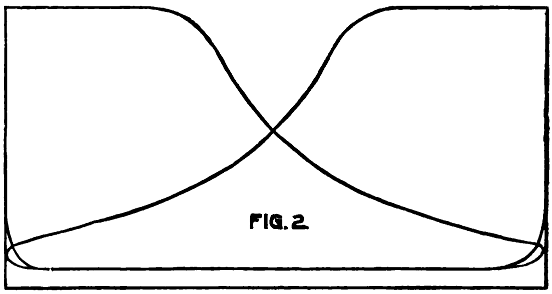


FIG. 2.

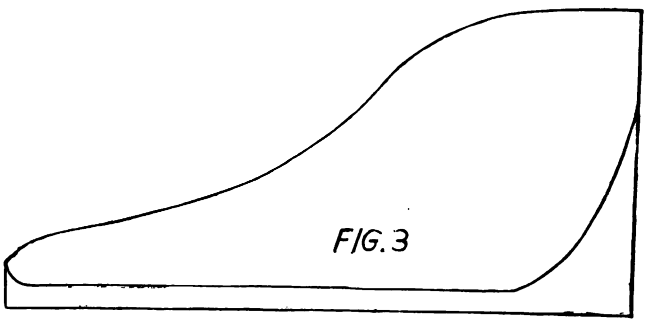


FIG. 3

The first two were taken from an 18 inch x 48 inch old style horizontal Corliss engine, running 50 revolutions per minute, the piston speed being 400 feet, furnishing part of the power for a rolling mill.

Of course the power required varied very much; at times the full power would be required, at others scarcely anything. The boiler being old, only a moderate pressure of steam could be used.

Fig. 1 was the first card that had been taken in a number of years; the

engine was one of a pair that had been used previously as auxiliary power in a cotton mill where they had water power sufficient to run most of the time.

The two engines were in about the same condition and were run side by side in the rolling mill, but were not connected, as each run separate trains of rolls, and in opposite directions. The exhaust from each engine ran into the same exhaust pipe, which operated unfavorably, which will be explained later on.

Fig. 2 shows a card taken after the valve seats had been bored out, valves turned, refitted and properly set.

What are the especially bad features, as shown in card one?

Too late! is plainly indicated in all the movements of the valves. The Corliss engine is known (by those familiar with steam machinery) as a four ported and four valve engine, controlled by one eccentric (the old style is here referred to); the steam valves are detachable by means of an "automatic cut-off" controlled by the governor. The steam valve (card one referred to) on the crank end did not open until the piston had travelled one-fifth or about nine inches of its stroke; the other end was not quite so bad, the steam valve opening at one-tenth or about five inches of the stroke.

What is the effect of this tardiness?

The steam could not get into the cylinder until the best time for efficient service had passed, and the effect of the most favorable opportunity for expansion had gone by and lost. By making the correction in steam line as shown in card, Fig. 2, the line is seen to rise perpendicular to the point of initial pressure at the beginning of the stroke, and runs horizontal to the point of cut-off, then expands gradually to the terminal pressure at the end of stroke, producing the full effect due to the regular diminishing pressure and expansion of the steam.

The next point of difficulty in card 1 is the late opening and closing of exhaust valves, which gives the heavy compression at the terminal of the stroke at each end, and the lack of compression of the exhaust to meet the direct steam at the admission line, which would give an easy action of the steam at the end of the stroke, upon the piston, thus avoiding unnecessary shock and pound.

There is another difficulty which seems appropriate to mention here, in reference to card 1. There is a serious leak in the exhaust valves as shown very strikingly at the hump, as seen in the line of the exhaust.

The average back pressure is about double that shown in card 2; the valves as shown in that card being now tight and properly set, the exhaust line is straight from the terminal to the admission of direct steam.

Allusion was made previously to the exhaust from both engines being made into the same pipe, which, being too small, cramps the exhaust of both, and in the case of card 2, if that engine had been provided with a separate exhaust pipe, there would have been but very little back pressure.

The data of both cards is here given:

FIGURE 1.

Steam 50 lbs., scale 30, M. E. P. 24.4 lbs.

Net Horse Power	75.22
Back Pressure	9.25
Gross Horse Power	84.47

FIGURE 2.

Steam 55 lbs., scale 30, M. E. P. 25 lbs.

Net Horse Power	77.
Back Pressure	7.7
Gross Horse Power	84.7

Those who are familiar with various types of automatic *cut-off* engines, understand that the Corliss style is what is termed a drop motion cut-off; that is, steam having followed the piston at very nearly the initial pressure, thus producing practically a horizontal line to the point of cut-off, the expansion then commences immediately, and gradually produces the hyperbolic curve or expansion to the terminal, as shown in Fig. 2.

With a positive motion cut-off as shown in cut, Fig. 3, we have somewhat different results. The action of the governor (it being a shaft or wheel variety) immediately controls the movements of the cut-off eccentric, which acts upon the cut-off valve, and gradually closes the opening until the point of cut-off is reached. While the result is sure in making a positive cut-off at each stroke at any point which the governor shall determine up to the end of the stroke, yet the steam line will show a slightly diminished pressure from the initial to the point of cut-off, which point is rather difficult to exactly determine, as seen in the cut. The expansion line is quite as good as in any other form of cut-off.

In the drop motion cut-off, in case of accident, if the valve rod should not hook on or become detached at the proper time, the steam would not enter or cut off as the case might be, and thus irregular speed would result which might lead to accident, and probably serious results might follow.

Referring again to the cut, Fig. 3, we find the steam line very smooth and gradual in reduction of pressure from the point of initial to terminal pressure, but more abrupt after cut-off has taken place.

In regard to the exhaust valves, the effect is most excellent, the exhaust valve closed, when compression begun at four-fifths of the stroke.

The compression line gradually meets the admission line, thus saving much direct steam. The engine passed the centres very smoothly without jar or pound, although running at quite high speed. This card may be considered as a fair sample of Cummer engine cards.

Data as follows:

16″ Diameter of Cyl.
30″ Length of stroke.
125 Revolutions per minute.
Boiler pressure 80 lbs. Scale 50.
Back " 6 "
Mean Effective pressure 39.4 lbs.
Net H. P. 149.38
Back Pres. 22.68

Gro. H. P. 172.06

REDUCING MOTIONS.

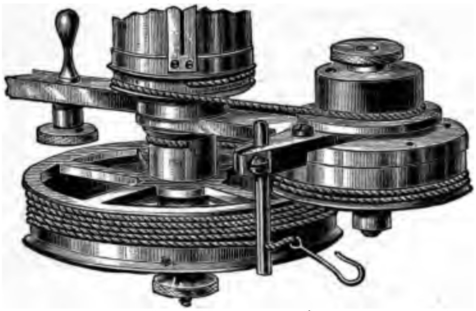
Those of the lever variety are described and illustrated on page 12.

The reducing wheel is a good device and is fast coming into general use. There are several styles made, most of them attached to the bottom of the indicator; in many respects this is a great convenience. They are readily adapted to any style of indicator, if the make is mentioned before ordering.

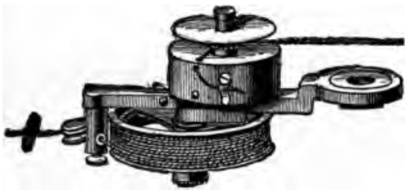
The wheel motions are got up with aluminum wheels and fine workmanship. They work very smooth and are well adapted for high speed, and by a change of one bushing can be readily arranged for any length of card or stroke.

They can also be fitted to a bracket to be placed on the cylinder head in a convenient position to use on a tandem engine to operate two indicators.

Two cuts of different manufacture are here shown, both are good devices.



"THE VICTOR."



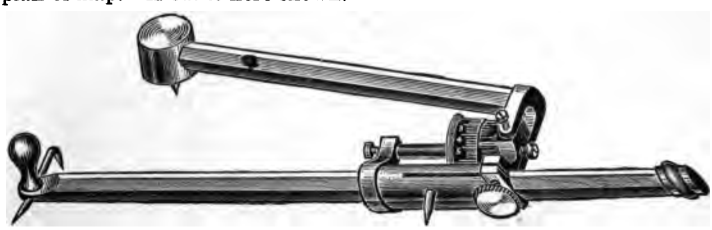
"THE IDEAL."

"STANDARD" AVERAGING PLANIMETER.

In addition to that shown on page 10 this instrument is also accurate and gives the *mean effective pressure* without computation when a 40 spring is used. Set the instrument the length of the card. When other springs are used a table of factors is here given for the different springs.

Springs,	8	12	16	20	24	30	40	50	60	80	100
Factors,	0.2	0.3	0.4	0.5	0.6	0.75	1.0	1.25	1.5	2.0	2.5

By setting the instrument at 4 inches between the points, it will register square inches for any irregular surface, for plans or maps it will give the result in square feet or miles, by multiplying by the square of the scale of the plan or map. A cut is here shown.



RELATIVE POWER OF DIFFERENT SEASONED WOODS, COALS, ETC., AS FUEL, TO PRODUCE HEAT—THE WOODS SUPPOSED TO BE SEASONED TO MEAN DRYNESS (77½ PER CENT.), AND THE OTHER ARTICLES TO CONTAIN BUT THEIR USUAL QUANTITY OF MOISTURE.

	Ratio Heating Power per equal	
	Bulk.	Weight.
Hickory, shell-bark	1.00	1.00
" red-heart	.81	.99
Ash, white	.77	.98
Beech, red	.65	.99
Chestnut	.49	.98
Elm, white	.58	.98
Maple, hard	.60	.98
Oak, white	.81	.99
" red	.69	.99
Pine, white	.42	1.01
" yellow	.48	1.03
Birch, black	.63	.99
" white	.48	.99
Coal, Cumberland (bit.)	2.41	2.28
" Lackawanna (anth.)	2.07	2.22
" Lehigh "	2.17	2.03
" Newcastle (bit.)	1.91	1.96
" Pictou, "	2.01	1.91
" Pittsburg, "	1.62	1.82
" Peach Mountain (anth.)	2.48	2.29
Charcoal	1.14	2 53
Coke, Virginia, natural	1.71	2.12
" Cumberland	1.19	2.25
Peat, ordinary		.62
Alcohol, common		2.02
Beeswax, yellow		2.90
Tallow		3.10

NOTE.—By help of the preceding table, the price of either one article being known, the relative or par value of either other, as fuel, may be readily ascertained:

EXAMPLE.—Maple (60) : $5.00 :: Pine (42) : $3.50.

WATER CONSUMPTION.

By permission, the following diagrams and explanations were taken from Buckeye Engine Co.'s catalogue:—

Having found the M. E. P., as previously explained, we next want the terminal pressure, which is found by extending the expansion curve to end of the diagram, and measuring from that point to vacuum line by the scale of the diagram. (See T V, Fig. 16.)

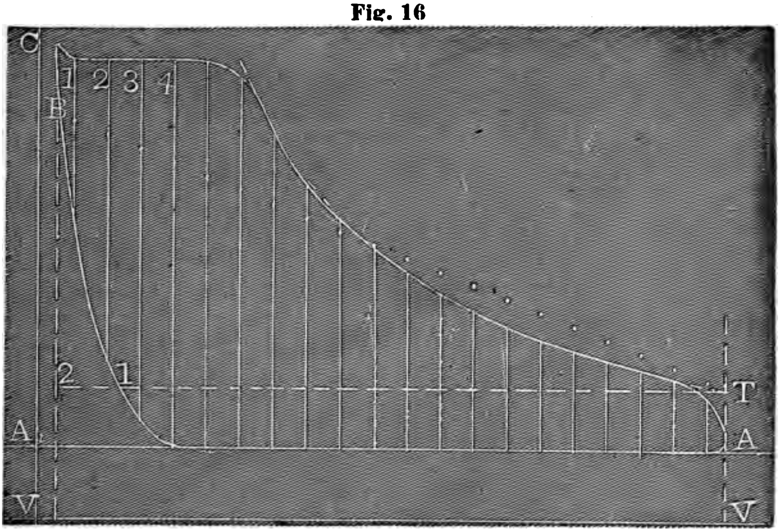
The economy of a steam engine.—This is expressed in terms of the number of pounds of water consumed per H. P. per hour. The rate of

water consumption is the only intelligible expression for the engine alone, as the amount of fuel used must depend largely upon the kind of boiler and its condition, the manner in which it is set and fired, the quality of the fuel, the draft, and numerous other conditions, for which the engine is in no way responsible.

This rate may be found by the following rule: Divide the constant number 859,375 by the volume of steam at the terminal pressure, and by the mean effective pressure. The quotient will be the desired rate.

This constant is the number of pounds of water that would be used in one hour by an engine developing one H. P. if run by water (instead of steam) at one pound pressure per square inch. Then, with pressure of more than one pound the amount required would be as many times less as the pressure was greater than one pound, and when steam is used, the amount would be as much less as the volume of the steam at the pressure at which it is released is greater than that of an equal weight of water. Hence the above rule. The constant is found as follows: The standard H. P. being 33,000 foot-pounds, or 33,000 lbs. lifted one foot per minute, would be equivalent to 33,000×12=396,000 lbs. lifted one inch per minute. Hence an engine whose piston displacement was 396,000 cubic inches per minute, would develop one H. P. with one pound M. E. P. on the piston. This for one hour would be 396,000×60 minutes=23,760,000 cubic inches per hour. Then suppose the engine to be run by water at one pound pressure per square inch, instead of steam, and taking the number of cubic inches of water per lb. at 27.648, 23,760,000÷27,648=859,375, which is the desired constant.

Fig. 16



EXAMPLE:—Diagram Fig. 16 was taken from our 12x20 inch automatic engines, speeded 140 revolutions per minute. Scale of diagram, 40 lbs. per inch. Applying the rule of analysis, we find first that the combined length of the 20 lines, 1, 2, 3, 4, etc., is $21\frac{1}{10}$ inches, showing that we have $42\frac{2}{10}$ lbs. M. E. P.

The terminal pressure (T. V.) is 27 lbs.; the volume at that pressure is *given at 926; that is,* one cubic inch of water at a temperature of 60°, makes

926 cubic inches of steam at 27 lbs. pressure per square inch. Hence by the rule the rate of water consumption becomes $\frac{849375}{926\times42.2}$=21.74 lbs. of water per I. H. P. per hour.

But early exhaust closure saves some steam, while exhausting from the clearance at a pressure greater than the back pressure wastes some, and the process, so far, makes no allowance for either. When the maximum compression equals the terminal, the loss and gain are equal, but when the compression exceeds the terminal, there is a balance of gain from compression equal to the excess of steam compressed into the clearance space over that exhausted from it, and when the terminal exceeds the compression, there is a balance of loss due to exhausting from the clearance space, hence the following rules:—

To make allowance for compression and clearance. 1st. Fix the terminal pressure at point T (Fig. 16 and other diagrams), where it would have been if the steam had not been released till the end of the stroke was reached.

2d. Draw the line T 2 parallel with the atmospheric line, which will cut the compression line at 1, at which point the quantity of steam exhausted from the clearance has been restored, and the consumption will be as much less than the rule shows, as the line T 1 is shorter than the line T 2, or the length of the diagram.

3d. Multiply the result obtained by the rule by the length of the line T 1, and divide the product by the length of the line T 2. The result will be the rate of consumption corrected for both clearance and compression.

EXAMPLE.—The result obtained from the rule is 21.74 lbs., the length of line T 1 is 3.17 inches, and the length of line T 2 is 3½ inches, hence 21.74×3.17÷3.5=19.69 lbs. per I. H. P. per hour, the corrected rate. It should be understood that this rate is theoretical, and assumes perfect conditions, such as dry steam, entire absence of loss from leakage, condensation, etc.

Fig. 17.

Fig. 17 illustrates our method of finding the point 1 (T 1) in the terminal line, when the line is located below the atmospheric line, and conse-

quently below any part of the compression curve defined on the diagram.

Select any point in the actual curve, as at D. From that point draw a line at right angles to atmospheric line, to terminal line, as at E. Then from V, where the clearance line cuts the vacuum line, draw a diagonal line through point E to point F (same height as point D), then a line at right angles to atmospheric line from F will cut the terminal line at the proper place for point 1. The process will be recognized the same in principle as that used for finding a point in the isothermal expansion curve.

The consumption for Fig. 17 is as follows:—

The M. E. P. is 2 lbs., and the T. P. is 6¾ lbs. The volume for 6¾ lbs. is given as 34.27 (the mean for 6½ and 7lbs.), hence $\frac{859375}{3427 \times 2}$=125.4 lbs. Line T 1 is 2¾ inches long, and line T 2 (or whole length of card) is 3½ inches, hence 125.4×2.75÷3.5=98,53 lbs. per I. H. P. per hour, the correct rate. This will serve to show the utter absurdity of very light loads.

Fig. 18.

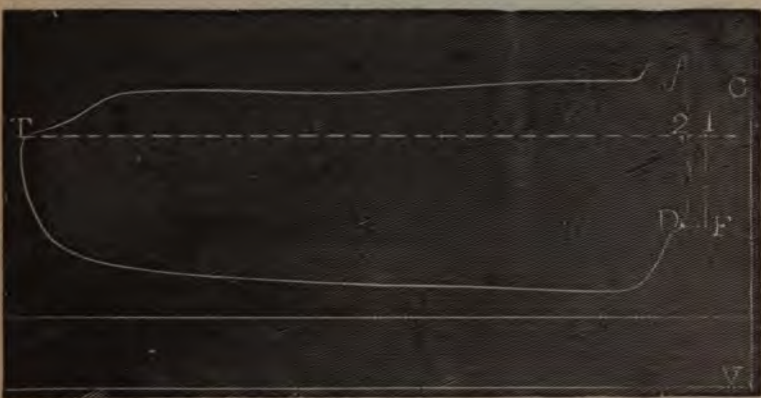


Fig. 18 illustrates a method of locating the clearance line from the conformation of compression curve, as follows: First select two points in the curve and form a parallelogram through said points as illustrated. Then draw a diagonal line through points F 2, till it intersects the vacuum line, the clearance line will be a vertical one drawn from said point of intersection, as at V. The degree of accuracy will depend upon the perfection or tightness of piston and valve, leakage generally having the effect of showing too much clearance.

In diagrams like Fig. 19, wherein no compression is present, the proper place for point 1 on the terminal pressure line can be found as follows: First, locate a clearance line in accordance with the best data at hand, draw a diagonal line from the intersection of terminal pressure line with the end of diagram, to intersection of clearance line with vacuum line (see 2 V), the diagonal line will cross a continuation of the back pressure line immediately under the proper place for point 1 on terminal line. In this case the result obtained from the rule will be increased, because the multiplier (distance T 1) is the larger number in the correction. A knowledge of existing clearance is necessary, as such diagrams furnish no clue to it. But the expansion curve of a cut-off diagram does furnish a clue to the volume of clearance, *unless the* curve is vicious in its formation.

Fig. 19.

The computation table on page 41 furnishes a very short and accurate method of finding the rate of water consumption due to indicator diagrams. The mean effective pressure being the **measure of *the power developed***, and the total terminal pressure (T. T. P.) the **corresponding measure** of the consumption or ***cost of the power***, **it follows that we should find a** number, which, if multiplied by the T. T. P. **and divided by the M. E. P.**, will give the rate of water consumption at once, **excepting, in many cases**, a required correction for compression and clearance.

Thus far the constant number 859,375 in connection with the volumes of steam, has been used for computing the rate of water consumption. To make the process available, a table of volumes must always be present, and to render our instructions complete we should publish such a table, but in lieu of that, we submit on page 41 a computation table as above stated.

EXPLANATION.—The numbers in P columns are so many T. T. P.'s and the numbers in column W are the numbers sought, as previously referred to above. Each of the numbers under W will therefore represent the rate of water consumption, for a diagram having both M. E. P and T. T. P. the same as the number to the left of it under P, and when any given diagram has a M. E. P. greater than its T. T. P. its rate of consumption will be proportionately less than if they were the same, and if the M. E. P. is less, the rate will be proportionately higher.

Hence the rule. Find in column P the total terminal pressure of the diagram or the number nearest it. (For fractions of a pound in the terminal, an approximate average of or mean of two numbers should be found, to insure accurate results.) Then multiply the number under W opposite the number so found by the T. T. P. of the diagram, and divide the product by its mean effective pressure the quotient will be the rate in pounds of water per I. H. P. per hour, subject, however, to the corrections for compression and clearance, as previously explained.

EXAMPLE FOR USE OF TABLE.—Referring to Figs. 16 and 17. First, Fig. 16, its terminal pressure is 27 lbs., M. E. P. 42.2, number under W for 27 lbs. is 34.37: T 1, 3.17 inches, and T 2, 3.5 inches. Then $34.37 \times 27 \div 42.2 = 21.99$ lbs. water. Correction, $21.99 \times 3.17 \div 3.5 = 19.91$ lbs. water per I. H. P. per hour, rate correction. For Fig. 17, terminal pressure is 6.75 lbs., and its M. E. P. is 2 lbs.; the number under W for 6¾ lbs. is 37.3 (got by adding to the number for 7 lbs., ¼ the difference between numbers for 6 and 7 lbs.) The distance T 1 is 2¾ inches, and the distance T 2 is 3½ inches. *Then* $37.3 \times 6.75 \div 2 = 125.89$ lbs. water. Corrected for clearance and com-

pression, 125.89×2.75÷3.5=98.91 lbs. water per I. H. P. per hour, the theoretical rate properly corrected.

The reader may notice that the result obtained by the use of the rule does not agree exactly with that obtained by the use of the constant number and the volumes. This arises from the fact that the tables of volumes published are not exact, but are the nearest approximation without using decimals. On preparing our table and carrying out the numbers to two decimal places, these inaccuracies produced very noticeable irregularities, and in order to correct them we selected several points along in the volume tables that proved most nearly correct, and then reduced the intermediate points to a curve cutting these points. The result is, our table will be found more accurate and reliable than any of the tables of volumes published. The process is independent of any knowledge of the size and speed of the engine,—a diagram and its scale being all the data that is required.

PRACTICAL HINTS ON MANAGEMENT.

To a competent engineer, the following advice would be deemed unnecessary, as all have their own methods of arriving at the same results. In the care of bearings, keying up and tightening, attention to oiling, avoiding unnecessary heating, packing, keeping joints tight, and other minor matters, are only thoroughly acquired by care, watchfulness and good judgment. One having these necessary qualifications and a desire to become a successful engineer will *succeed.* If he is a good mechanic and practical machinist in building steam engines. so much the better. If he has not any of these qualifications, he had better get into some other business as soon as *possible* and make room for those who have.

In keying up a connection, a very good plan is to drive the key hard with a soft metal hammer, and if you have not a permanent mark make a temporary one with your greasy thumb across the gib and key next to the strap. Drive the key back as much as is necessary to prevent heating. If the crank, pin, or any part is out of line, it will require to be looser than otherwise. If you are in doubt where the pound is, put on a little oil (when the engine is working); the pound will stop for the instant, if you have found the right place.

The best cure for heated bearings is, not to let them *heat*, but with the best engineers this will happen sometimes. A good remedy for large bearings is fine plumbago and sperm oil if it can be obtained, otherwise castor or good lubricating oil, or take off the top box (when there is not a large hole in it), and while the shaft is slowly turning put on white lead ground in oil from the keg. When the lead is seen coating the bearings as it turns slowly, it shows that the lead has interposed itself between the two surfaces and will cool down, when the ordinary lubricant may be resumed.

Avoid using water if possible, but do not endanger melting out boxes and cutting bearings, by *not* using it. Much judgment is required about these things. Many a fine engine has been ruined by want of attention, at the proper time, to these important matters.

STEAM PUMPS.

A proper management of pumps is very important. With a steam pump *a very slight thing* often will prevent the pump from working, per-

have a little chip or dirt under the valves, or stoppage of the small steam holes or ports. Have a suitable strainer in the water supply pipe at some accessible point.

So much depends on the pump for water to supply the boilers, that a good deal of close attention is required in this direction. Be sure that the feed valve to the boiler is open before starting the pump. Where Injectors or Inspirators are used, you cannot use the supply water so hot, or graduate your feed as well as with a steam pump.

We insert directions from Deane Pump Co., in relation to steam pumps.

In ordering a pump, it is important to the buyer's interest that he should inform the party of whom he purchases on the following points:—

1. For what purpose is it to be used?
2. What is the liquid, or semi-liquid, to be pumped, if not water?
3. If water, is it hot or cold, salt or fresh, clear or gritty?
4. What is the maximum quantity required to be pumped per hour?
5. To what height is it to be lifted by suction, and to what height forced?
6. What is the whole length of suction pipe, and what of discharge pipe?
7. What is the ordinary pressure of the steam used?

In ordering parts for, or in otherwise referring to a pump in use, not merely the number designating the size should be given, but also the factory number.

Directions for Setting Up and Operating Pumps.

In setting up a pump, the first requisite is to provide a full and steady supply of water (or other fluid). To accomplish this, observe the following points:—

The suction pipe must in no case be smaller than the size given in the table; if long, it must be larger, as the friction due to unusual length will partly overcome the head due to the vacuum, and prevent a full supply.

It must be as straight and free as possible, for turns and valves obstruct the water far more than length of pipe.

It must be air tight, as a very small leak will supply the pump with air to its full capacity, so that little or no water will be obtained, according to the size of the leak.

Foreign substances—such as sticks and rubbish—must not be allowed to enter the suction pipe. If there is danger of it, a strainer must be used. The aggregate area of strainer holes—on account of the added friction—must be from two to five times the area of the pipe, according to the speed at which the pump is to be run.

A foot valve must be used on long or high suctions. If one is used, see that it has as large an area as the pipe. The smallest point in the pipe is practically the size of the whole.

A suction air chamber, on the suction pipe near the pump, is always an advantage on long or high suctions, or when high speed is desired it is a necessity. It prevents pounding when the pump reverses.

Hot water cannot be raised to any considerable height by suction. If the supply is very hot, it must be placed high enough so that the water will flow to the pump by gravitation.

The steam, exhaust and discharge pipes should be straight and free as possible.

To prevent freezing, when a pump is idle in cold weather, drain it by opening all cocks and plugs provided for the purpose.

Keep the steam cylinder oiled, especially just before stopping.

Keep all stuffing boxes well and evenly filled with packing, so they need not be screwed too tight.

Let the steam end alone, if the pump begins to run badly, until fully satisfied that there is no obstruction in the water cylinder, water valves or water pipes.

Don't pull the pump apart to see what is inside, as long as it does its work well.

Use a pump well and carefully, if it is expected to work well.

USEFUL INFORMATION.—Applicable to Pumps.

A gallon of water (U. S. Standard) weighs 8⅓ pounds and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

Each nominal horse-power of boilers requires one cubic foot of water per hour.

In calculating horse power of steam boilers, consider for tubular or flue boilers 15 square feet of heating surface equivalent to one horse power.

Condensing engines require 20 to 25 gallons of water to condense the steam evaporated from one gallon of water.

To find the pressure in pounds per square inch of a column of water: multiply the height of the column in feet by .434. (Approximately, every foot elevation is called equal to one-half pound pressure per square inch.)

To find the capacity of a cylinder in gallons: Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a gallon in inches), and the product is the capacity in gallons.

Ordinary speed to run pumps is 100 feet of piston per minute.

To find quantity of water elevated in one minute running at 100 feet of piston per minute: Square the diameter of water cylinder in inches and multiply by 4. EXAMPLE:—Capacity of a 5-inch cylinder is desired: The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, which is gallons per minute, (approximately.)

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the speed), divide the number of gallons by 4, then extract the square root, and the result will be the diameter in inches.

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time. multiply the number of cubic feet of water by 144 and divide the product by the area of the pipe in inches.

To find the area of a required pipe, the volume and velocity of water being given, multiply the number of cubic feet of water by 144, and divide the product by the velocity in feet per minute. The area being found, it is easy to get the diameter of pipe necessary.

The area of the steam piston multiplied by the steam pressure, gives the total amount of pressure exerted. The area of the water piston multiplied by the pressure of water per square inch gives the resistance. A margin must be made between the power and resistance, to move the pistons at the required speed; usually reckoned at about 50 per cent.

TABLE.

SHOWING GALLONS OF WATER DISCHARGED IN FIRE STREAMS THROUGH 100 FEET OF 2½-INCH RUBBER HOSE, WITH GIVEN NOZZLES (SMOOTH).

Diam. of Nozzle.	Pressure at Nozzle.	Gallons per Minute.	Horizontal Stream.	Vertical Stream.	Diam. of Nozzle.	Pressure at Nozzle.	Gallons per Minute.	Horizontal Stream.	Vertical Stream.
1	30	134	90	62	1⅛	70	259	163	125
1	40	155	109	76	1⅛	80	277	175	137
1	50	173	126	94	1⅛	90	294	186	148
1	60	189	142	108	1⅛	100	310	193	157
1	70	205	156	121	1¼	30	210	96	63
1	80	219	168.	131	1¼	40	242	118	82
1	90	232	178	140	1¼	50	271	138	99
1	100	245	186	148	1¼	60	297	156	115
1⅛	30	170	93	63	1¼	70	320	172	129
1⅛	40	196	113	81	1¼	80	342	186	142
1⅛	50	219	132	97	1¼	90	363	198	154
1⅛	60	240	148	112	1¼	100	383	207	164

LOCOMOTIVE AND MARINE ENGINES.

What has been said in regard to stationary boilers and engines is true in reference to the locomotive and marine service to a considerable extent. Locomotive boilers require closer watching of the water, as the boiler is constantly in motion, and the water used is not generally so free from impurities, being obtained from a variety of sources, particularly at the West and South. Hence the boiler should be blown out more frequently, and examined with great care. The engine being on an uncertain foundation (especially if the road-bed is in a bad condition), is liable to be constantly out of line, the only dependence being the stability of the frame. But locomotive builders understand this thing and pay particular regard to it. But, nevertheless, the boxes will not run, keyed up as tight as with a stationary. Hence the engineer must give this matter close attention.

As the subject of setting of the valves has been alluded to previously in reference to the locomotive, it is not necessary to refer to it at any length here. The speed of the engine, whether it be a freight or fast express, regulates the necessary lead, and as the draft is regulated and controlled by the exhaust in most cases, proper attention should be given to the lead of the exhaust valve. The size of outlet of exhaust pipe has much to do with the draft. No special rules can be given for these matters. All must depend upon the judgment of those having it in charge.

Marine or river boat engines and boilers are subject to similar conditions as stationary except in the former boilers. Salt water is often used as a matter of necessity, but most of the large steamships of the regular lines are provided with tanks for fresh water, and have condensing apparatus so as to avoid the use of salt water, with all its attendant evils of formation of scale, etc. But where salt water is used, frequent blowlng-off is necessary, both from the surface and from the bottom; use also the salinometer often, to test the saline properties of the water, particularly on long voyages. On western river boats where the water is very muddy, frequent blowing-off is imperative.

In the marine or boat engine, the only foundation is the ship or boat, and if fastened securely to it in line with the keel itself, that is all that can

be done. But in putting in the machinery, the utmost care should be taken to have all the parts in line with the main shaft, or line where the main shaft is to be. All the work of course has to be placed by line, as no *plumb* or *level* can be used on a vessel afloat. The management of the engine is the same as on the land, except that, as in the case of the locomotive, convenient provision is made for reversing (by means of double eccentrics and links, or otherwise), that is, running forward or backward, as the signal of the conductor or pilot may dictate by means of the wave of the hand or lantern, or the stroke of the signal gong.

STEAM HEATING.

No positive rules can be given for steam heating, as the conditions are so varied, dependent upon locality, climate and heat required. But in the vicinity of New York we can approximate very near for all general purposes. The rule of Watt was to allow 1 cubic foot of water per hour for each horse power; hence if we measure the water condensed in the heating pipes in a given time, allowing 62.5 lbs. per cubic ft. or 7.68 gallons per cubic foot, we can get very near the quantity of steam.

Steam pipes in the ordinary circulation when run around the sides of the apartment, keeping the temperature at 60°, will condense .357 lbs. of water per hour for each square foot of surface of pipe. A coil maintaining the same temperature will condense .29 lbs. (per hour, per sq. ft.) of surface. For dwellings, when the pipes in the form of coils are placed in the cellar and supplied with air from the outside, one square foot of pipe surface, or three lineal feet of 1-inch pipe to 50 cubic feet of space to be warmed, when the coil is placed in the apartment, the same amount of surface of pipe to 65 cubic feet of space; in workshops the same amount of pipe to 100 feet of space; in stores and warehouses the same quantity of pipe to 150 to 200 feet of space. Exhaust or low pressure steam is generally considered the best economy for heating in manufacturing establishments, where there is plenty of it (in such cases the cost of steam for power is very slight); if the back pressure does not exceed 6 or 8 lbs. per square inch, there is no serious difficulty in running it through 1-inch pipes as long as there is enough area. For stores and dwellings low pressure steam is preferable.

ELECTRIC LIGHTS.

This subject is occupying much attention at the present time. While it is conceded by many scientists that electricity may be the great medium of light, power and heat, for light only has it as yet assumed a tangible shape, so as to meet with any degree of success. We have gone into very minute calculations from practical observations of the working of the Arc and Incandescent system (known as the Weston and Maxim plan), in comparison with gas, as has been used the past two years in one of the prominent Lowell mills. The following statistics give the result:—

The price in this statement is given as per burner, or electric lamp. per hour, in order to readily determine the cost of each for any special outfit.

Relative cost of gas and electric lights: Price of gas $1.50 per thousand feet; coal for electric light power, $5.00 per ton.

No. 1 WEAVE ROOM.

	Mills
440 4-foot gas burners, gas consumed, each per hour	6.9
Repairs for burner	1.14
Interest on plant $2500 at 6%	3.9
Cost per burner per hour	11.94
Whole cost of 440 burners per hour	$5.25

440 24-candle power Incandescent lamps each.

Fuel per lamp per hour, being 8 lamps per horse power	.90
Repairs per lamp per hour	.81
Care of dynamos, and oil	.16
*Interest on plant $5250 at 6%	8.04
Cost per lamp per hour	9.91
Whole cost 440 lamps per hour, being 8 lamps per horse power	$4.36

Whole cost 440 gas burners per hour	$5.25
Whole cost 440 lamps per hour	4.36
Cost of gas more than electric light, equal 20%	.89

No. 1 CLOTH ROOM.

	Cents.		Cents.
46 5-foot gas burners; whole cost each per hour	1.366	whole	62.83
6 Arc lights; whole cost each per hour	3.113	"	18.67
Cost of gas more than electric lights, equal 236%			44.16

On same basis of cost in other mills.

472 4-foot gas burners, each 11.94, cost per hour	$5.63
472 16-candle incandescent lamps, cost per hr., being 12 lamps per h.p.	3.11
Cost of gas more than electric light, equal 81%	2.52

No. 2 CLOTH ROOM.

	Cents.		Cents.
38 5-foot gas burners, cost each per hour	1.366	whole	51.90
4 Arc lights, cost each per hour	3.113	"	12.45
Cost of gas more than Arc lights, equal 316%			39.45

Cost per year, gas	$6945.75
" " " electric light	4493.64
" " " of gas more than electric lights, equal 54%	2452.11

The above is based on 165 days service of 3½ hours per day.

NOTE.—In consequence of the great reduction in price of electric light machinery and supplies since the first edition of this work was published, an entire revision of the above statement was thought best.

* Steam engine and boiler plant not included. When used independent of other power, interest on cost of engine plant, and expense of engineer and fireman should be added.

TABLE

Showing the oxygen consumed, the carbonic acid produced, and the air vitiated by the combustion of certain bodies burnt so as to give the light of twelve standard sperm candles, each candle burning at the rate of 120 grains per hour:—

Burnt to give light of 12 candles, equal to 120 gr. per hour.......	Cubic feet of oxygen consumed..	Cubic feet of air consumed......	Cubic feet of carbonic acid produced..........	Cubic feet of air vitiated........	Heat produced in pounds of water raised 10° F....
Cannel Gas..............	3.30	16.50	2.01	217.50	195.0
Common Gas...........	5.45	17.25	3.21	348.25	278.6
Sperm Oil................	4.75	23.75	3.33	356.75	233.5
Bensole..................	4.45	22.30	3.54	376.30	232.6
Paraffin......	6.81	34.05	4.50	484.05	361.9
Camphine................	6.65	33.25	4.77	510.25	325.1
Sperm Candles...........	7.57	37.85	5.77	614.85	351.7
Wax......................	8.41	42.05	5.90	632.25	383.1
Stearic................ ...	8.82	44.10	6.25	669.10	374.7
Tallow..................	12.00	60.00	8.73	933.00	305.4
Electric Light...........	none	none	none	none	13.8

There you see why the electric light is so pure and so healthy. There is no consumption or pollution of air. There is the smallest possible production of heat. There are none of the existing dangers from fire or suffocation but all is pure, healthy and safe.—[Electrical Review.

SHAFTING.

In putting up shafting, care should be taken to place the main line parallel and level with engine or line of water wheel. If those are not already in, they should be so placed as to be in line with the walls of the building where the main line is to run. Always place the engine if possible, in such a position so that the main belt will be at an angle of about 35° with the floor, and sufficiently distant from the main line to cause the belt to sag from 4 to 6 inches in its length, dependent upon the width of belt and power required to transmit, and have the bottom side the driving or tight side. Whatever slack there may be, will fall upon the top side of the pulleys and give additional power. Do not place the face of a driven pulley, perpendicular to that of a driver if it can be avoided. In making a quarter turn with the belt, the best plan is to use a (mule stand) which is a perpendicular shaft with two idle pulleys upon it. It should be placed not less than 10 times the width of the belt from the shaft. If the two shafts are on the same plane, or level, the idlers can also be level, but if not, they must be placed at such an angle and position as the distance from the face of the top side of the driving pulley around the centre of the upper idler to the top of the driven pulley shall be the same as the distance from the bottom side of the driven pulley around the centre of the bottom idler to the bottom side of the driver.

The mistake is often made that a belt will always run to the highest *point on a pulley. This* is true when the two lines of shaft are level or

parallel with each other, but if not, the belt will run to the nearest point, and the only way to prevent it is to place the driven shaft in line, or parallel with the driver, or enlarge the slack edge of the driven pulley until its face is parallel with the driver. The latter expedient is not recommended, as it would soon spoil the belt. In placing a shaft for a quarter turn where the driven shaft is 10 ft. above or below, the centre of the face of driving pulley on the driving side should be perpendicular to the driven edge of the driven pulley. These points with a good mechanic are soon learned by experience.

MISCELLANEOUS.

In the succeeding pages it is proposed to treat of the various subjects that come into the general practice of the thorough engineer and mechanic, in the course of which, illustrations, rules and tables are given to facilitate calculations in connection therewith, while much of it is new the balance is made up with careful selections from known reliable authors as best adapted to this work (for which due credit is given.) It is hoped that much valuable information may be gained from its study.

TABLE

OF SIZES OF PATENT COLD-ROLLED SHAFTING, PISTON AND PUMP RODS.

Diameter	Wei't pr ft.	Diameter.	Wei't pr ft.	Diameter.	Wei't pr ft.	Diameter.	Wei't pr ft.
4½	53.76	2⅜	14.76	1½	5.89	13-16	1.74
4	41.88	2¼	13.25	1 465-1000	5.52	¾	1.47
3¾	36.81	2 3-16	12.54	1 7-16	5.41	11-16	1.24
3½	32.07	2⅛	11.82	1⅜	4.94	⅝	1.02
3¼	27.65	2	10.47	1 5-16	4.51	9-16	.837
3	23.56	1 15-16	9.83	1¼	4.09	½	.654
2 15-16	22.65	1⅞	9.20	1 3-16	3.70	15-32	.582
2⅞	21.63	1 13-16	8.65	1⅛	3.31	7-16	.511
2¾	19.79	1¾	8.01	1 1-16	2.96	43-100	.503
2 11-16	18.80	1 11-16	7.45	1	2.61	⅜	.368
2⅝	18.03	1⅝	6.91	15-16	2.36	5-16	.258
2½	16.36	1 592-1000	6.60	29-32	2.18	¼	.165
2 7-16	15.55	1 9-16	6.40	⅞	2.00		

Each shaft made to Whitworth gauge. The shafts are kept on hand in lengths of 20 feet, and are cut to any length desired.

BEARINGS OF SHAFTING.

In practice, long shafts are scarcely ever entirely free from transverse strains; however, in the parts of long lines, which have no pulleys or gears with the couplings near the bearings, the intervals between the bearings may approach the distances given in the preceding table. The last space should not exceed sixty per cent. of these given, the deflection in that space being much greater than in other parts of the line. In shafts moving with high velocities it will usually be necessary to shorten the distances between the bearings in order to obtain sufficient bearing surface to prevent heating.—[J. B. Francis.

TABLE

OF THE GREATEST ADMISSIBLE DISTANCES BETWEEN THE BEARINGS OF CONTINUOUS SHAFTS, SUBJECT TO NO TRANVERSE STRAIN EXCEPT FROM THEIR OWN WEIGHT.

Diameter of Shaft in inches.	Dist. between bearings in ft.		Diameter of Shaft in inches.	Dist. between bearings in ft.	
	Wrought iron	Steel.		Wrought iron.	Steel.
2	15.46	15.89	6	22.30	22.92
3	17.70	18.19	7	23.48	24.13
4	19.48	20.02	8	24.55	25.23
5	20.99	21.57	9	25.53	26.24

RULES FOR ASCERTAINING THE HORSE POWER OF SHAFTING.

The torsional strength of shafts, or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness, or resistance to bending, is proportional to the fourth power of their diameters, and varies inversely in proportion to their load and also to the cube of the length of their spans or "bay."

For head shafts supported by bearings close to each side of the main pulley or gear, so as to wholly guard against the transverse strain. The following formula affords an ample margin for strength:—

D=Diameter of shaft in inches.
R=Revolutions per minute.
H=Horse Power.

Cold rolled iron.

(a) $$H=\frac{D^3 \times R}{75}$$

$$D=\sqrt[3]{\frac{75H}{R}}$$

Turned iron.

(b) $$H=\frac{D^3 \times R}{125}$$

$$D=\sqrt[3]{\frac{125H}{R}}$$

Receiving and transmitting pulleys should always be placed as close to bearings as possible, and it is a good practice to frame short "headers" between the main tie-beams of a mill so as to support the main receivers, carried by the head shafts with a bearing close to each side as is contemplated in the formula. But if it is preferred, or necessary, for the shaft to span the full width of the "bay" without intermediate bearings, or for the pulley to be placed away from the bearings towards, or at the middle of the bay, the size of the shaft must be largely increased to secure the stiffness necessary to support the load without undue deflection. Shafts may not deflect more than 1-80 of an inch to each foot of clear length with safety.

To find the diameter of shaft necessary to carry safely the main pulley at the centre of a bay:—

Multiply the fourth power of the diameter obtained by above formula by the length of the bay, and divide this product by the distance from centre to centre of the bearings when the shaft is supported as required by the formula. The fourth root of this quotient will be the diameter required.

The following table, computed by this rule, is practically correct and safe:—

Diam. of shaft given by the formula for head shafts.	Diameter of shaft necessary to carry the load at the centre of a bay which is from centre to centre of bearings.							
	2½ ft.	3 ft.	3½ ft.	4 ft.	5 ft.	6 ft.	8 ft.	10 ft.
Inches.	In.	In.	In.	In.	In.	In.	In.	In.
2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3
2½	2½	2⅝	2¾	2⅞	3	3⅛	3⅜	3⅝
3	3	3⅛	3¼	3⅜	3½	3¾	4	4¼
3½		3½	3⅝	3¾	4	4¼	4½	4¾
4		4	4⅛	4¼	4½	4¾	5⅛	5⅜
4½			4½	4⅝	4⅞	5⅛	5½	5⅞
5			5	5⅛	5⅜	5⅝	6	6½
5½				5½	5¾	6	6½	6⅞
6				6	6⅜	6⅝	7⅛	7½

As the strain upon a shaft from a load upon it is proportional to the product of the parts of the shaft multiplied into each other; therefore, should the load be applied near one end of the span or bay, instead of at the centre, multiply the fourth power of the diameter of the shaft required to carry the load at the centre of the span or bay by the product of the two parts of the shaft where the load is near one end, and divide this product by the product of the two parts of the shaft when the load is carried at the centre. The fourth root of this quotient will be the diameter required.

Suppose, for example, that a shaft, to carry a certain load at the centre of an 8 feet bay is 4½ inches diameter, then: to carry the same load at a point 2 feet from one end.

$$\frac{(2\times6)\times410}{(4\times4)}=\sqrt[4]{307}=4 \text{ 3-16in.}$$

For line shafting from which power is taken at intervals. Bearings 8 feet apart.

Cold rolled iron.	Turned iron.
(c) $H=\dfrac{D^3\times R}{50}$	(d) $H=\dfrac{D^3\times R}{90}$
$D=\sqrt[3]{\dfrac{50H}{R}}$	$D=\sqrt[3]{\dfrac{90H}{R}}$

The shaft in a line which carries the receiving pulley, or which carries a transmitting pulley to drive another line, should always be considered a "head shaft," and should be of the size given by the rules for shafts carrying *main pulleys* or *gears*.

For simply transmitting power and short counters:—

Cold rolled iron.	Turned iron.
(*e*) $H=\dfrac{D^3 \times R}{30}$	(*f*) $H=\dfrac{D^3 \times R}{50}$
$D=\sqrt[3]{\dfrac{30H}{R}}$	$D=\sqrt[3]{\dfrac{50H}{R}}$

It is proper to say that some engineers (especially in cotton-mill practice) require from shafting much larger duty than the above formula gives. Under favorable conditions this is admissible, but for ordinary practice we believe that the sizes obtained by these formulas are as light as should be used.

TABLE.

TRANSMITTING EFFICIENCY OF COLD ROLLED IRON SHAFTING AT DIFFERENT SPEEDS. AS PRIME MOVER OR HEAD SHAFT CARRYING MAIN DRIVING PULLEY OR GEAR, WELL SUPPORTED BY BEARINGS.

(Calculated by formula *a*, page 71.)

Diam. of Shaft.	Number of revolutions per minute.										
	60	80	100	125	150	175	200	225	250	275	300
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
$1\frac{1}{2}$	2.7	3.6	4.5	5.6	6.7	7.9	9.0	10	11	12	13
$1\frac{3}{4}$	4.3	5.6	7.1	8.9	10.6	12.4	14.2	16	18	19	21
2	6.4	8.5	10.7	13	16	19	21	24	26	29	32
$2\frac{1}{4}$	9	12	15	19	23	26	30	34	38	42	46
$2\frac{1}{2}$	12	17	21	26	31	36	41	47	52	57	62
$2\frac{3}{4}$	16	22	27	35	41	48	55	62	70	76	82
3	21	29	36	45	54	63	72	81	90	98	108
$3\frac{1}{4}$	27	36	45	57	68	80	91	103	114	126	136
$3\frac{1}{2}$	34	45	57	71	86	100	114	129	142	157	172
$3\frac{3}{4}$	42	56	70	87	105	123	140	158	174	193	210
4	51	69	85	106	128	149	170	192	212	244	256
$4\frac{1}{2}$	73	97	121	151	182	212	243	273	302	333	364

NOTE. The tables and explanations in reference to shafting, gearing, belting, etc., introduced here, were taken by permission from Messrs. Jones & Laughlin's book, compiled by C. C. Briggs. It gives very correct and reliable information on those subjects, and will be found useful for reference.

RULES FOR OBTAINING APPROXIMATE WEIGHT OF IRON.

Rule for Round Bars:—Multiply the square of the diameter in inches by the length in feet, and that product by 2.6. The product will be the weight in pounds, nearly.

Rule for Square and Flat Bars:—Multiply the area of the end of the bar in inches by the length in feet, and that by 3.32. The product will be the weight in *pounds, nearly*.

TABLE.

Transmitting Efficiency of Turned Iron Shafting at different speeds. As Prime Mover or Head Shaft carrying Main Driving Pulley or Gear, well supported by bearings.

(Calculated by formula *b*, page 71.)

Diam. of Shaft.	Number of revolutions per minute.										
	60	80	100	125	150	175	200	225	250	275	300
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1¾	2.6	3.4	4.3	5.4	6.4	7.5	8.6	9.7	10.7	11.8	12.9
2	3.8	5.1	6.4	8	9.6	11.2	12.8	14.4	16	17.6	19.2
2¼	5.4	7.3	8.1	10	12	14	16	18	20	22	24
2½	7.5	10	12.5	15	18	22	25	28	31	34	37
2¾	10	13	16	20	24	28	32	36	40	44	48
3	13	17	20	25	30	35	40	45	50	55	60
3¼	16	22	27	34	40	47	54	61	67	74	81
3½	20	27	34	42	51	59	68	76	85	93	102
3¾	25	33	42	52	63	73	84	94	105	115	126
4	30	41	51	64	76	89	102	115	127	140	153
4½	43	58	72	90	108	126	144	162	180	198	216
5	60	80	100	125	150	175	200	225	250	275	300
5½	80	106	133	166	199	233	266	299	333	366	400

TABLE.

Transmitting Efficiency of Turned Iron Shafting at different speeds. As Second Movers or Line Shafting. Bearings 8 feet apart.

(Calculated by formula *d*, page 72.)

Diam. of Shaft.	Number of revolutions per minute.										
	100	125	150	175	200	225	250	275	300	325	350
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1¾	6.	7.4	8.9	10 4	11.9	13.4	14.9	16.4	17.9	19.4	20.9
1⅞	7.3	9.1	10.9	12.7	14.5	16.3	18.2	20.	21.8	23.6	25.4
2	8.9	11.1	13.3	15.5	17.7	20.	22.2	24.4	26.6	28.8	31
2⅛	10.6	13.2	15.9	18.5	21.2	23.8	26.5	29.1	31.8	34.4	37
2¼	12.6	15.8	19	22	25	28	31	35	38	41	44
2⅜	15	18	22	26	29	32	37	41	44	48	52
2½	17	2	26	30	34	39	43	47	52	56	60
2¾	23	29	34	40	46	52	58	64	69	75	81
3	30	37	45	52	60	67	75	82	90	97	105
3¼	38	47	57	66	76	85	95	104	114	123	133
3½	47	59	71	83	95	107	119	131	143	155	167
3¾	58	73	88	102	117	132	146	162	176	190	205
4	*71*	*89*	*107*	125	142	160	178	196	213	231	249

RULES FOR CALCULATING SPEED OF PULLEYS.

Problem I. The diameter of the driver and driven being given, to find the number of revolutions of the driven:

RULE.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

Problem II. The diameter and revolutions of the driver being given to find the diameter of the driven, that shall make any given number of revolutions in the same time:

RULE.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

Problem III. To ascertain the size of the driver:

RULE.—Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the size of the driver.

The above rules are practically correct. Though, owing to the slip, elasticity, and thickness of the belt, the circumference of the driven seldom runs as fast as the driver,

Belts, like gears, have a pitch-line, or a circumference of uniform motion. This circumference is within the thickness of the belt, and must be considered if pulleys differ greatly in diameter, and a required speed is absolutely necessary.

NOTES ON BELTING.

Don't overtax belts by overloading them, or by running them tighter than necessary.

The whole arrangement of shafting and pulleys should be under the direction of a mechanical engineer or competent machinist. Destruction of machinery and belts, together with unsatisfactory results in the business, is a common experience which may, in most cases, be traced to want of knowledge and care in the arrangements of the machinery, and in the width and style of the belts bought, and in the manner of their use, while the manufacturers of the "outfit" are often blamed for bad results which are caused by the faulty management of the mill-owner himself.

Having properly arranged the machinery for the reception of the belts, the next thing to be determined is the length and width of the belts.

When it is not convenient to measure with a tape line the length required, the following rule will be found of service:

RULE.—Add the diameter of the two pulleys together, divide the result by 2, and multiply the quotient by $3\frac{1}{4}$, then add this product to twice the distance between the centres of the shafts, and you have the length required.

The width of the belt needed depends on three conditions: 1.—The tension of the belt. 2.—The size of the smaller pulley, and the proportion of the surface touched by the belt. 3.—The speed of the belt.

The working adhesion of a belt to the pulley will be in proportion both to the number of square inches of belt contact with the surface of the pulley, and *also to the arc* of the circumference of the pulley touched by

the belt. This adhesion forms the basis of all right calculation in ascertaining the width of belt necessary to transmit a given horse power.

In the location of shafts that are to be connected with each other by belts, care should be taken to secure a proper distance one from the other. It is not easy to give a definite rule as to what this distance should be. Circumstances generally, have much to do with the arrangement, and the engineer or machinist must use his judgment, making all things conform, as far as may be, to general principles. This distance should be such as to allow of a gentle sag to the belt when in motion.

A general rule may be stated thus:

RULE.—Where narrow belts are to be run over small pulleys—15 feet is a good average—the belt having a sag of 1½ to 2 inches.

For larger belts, working on larger pulleys, a distance of 20 to 25 feet does well, with a sag of 2½ to 4 inches.

For main belts, working on very large pulleys, the distance should be 25 to 30 feet, the belts working well with a sag of 4 to 5 inches.

If too great a distance is attempted, the weight of the belt will produce a very heavy sag, drawing so hard upon the shaft as to produce great friction in the bearings, while at the same time the belt will have an unsteady flapping motion, which will destroy both the belt and machinery.

If possible to avoid it, connected shafts should never be placed one directly over the other, as in such case the belt must be kept very tight to do the work. For this purpose, belts should be carefully selected of well-stretched leather.

It is desirable that the angle of the belt with the floor should not exceed 45°. It is also desirable to locate the shafting and machinery so that belts should run off from each shaft in opposite directions, as this arrangement will relieve the bearings from the friction that would result when the belts all pull one way on the shaft.

The diameter of the pulleys should be as large as can be admitted, provided they will not produce a speed of more than 3750 feet of belt motion per minute. Some authorities limit this speed to 3000.

The pulleys should be a little wider than the belt required for the work.

The motion of driving should run with and not against the laps of the belts.

Tightening or guide pulleys should be applied to the slack side of belts and near the smaller pulley.

Quick-motion belts should be made as straight and as uniform in section and density as possible, and endless if practicable, that is, with permanent joints.

Belts which run loose will, of course, last much longer than those which must be drawn tightly to drive—tightness being evidence of overwork and disproportion.

Never add to the work of a belt so much as to overload it.

The transmitting power of a double bolt is to that of single belt as 10 is to 7. In ordering pulleys, the kind of belt to be used should always be specified.

The strongest part of belt leather is near the flesh side, about ⅓ the way through from that side. It is therefore desirable to run the grain (hair) side on the pulley, in order that the strongest part of the belt may be subject to the least wear.

The flesh side is not liable to crack, as the grain side will do when the belt is old, hence it is better to crimp the grain than to stretch it.

Leather belts run with grain side to the pulley will drive 30 per cent. more than if run with flesh side. The belt, as well as the pulley, adheres

best when smooth, and the grain side adheres best because it is smoothest.

A belt adheres much better and is less liable to slip when at a quick speed than at a slow speed. Therefore it is better to gear a mill with small pulleys and run them at a high velocity than with large pulleys and to run them slower. A mill thus geared costs less and has a much neater appearance than with large heavy pulleys.

Belts should be kept clean and free from accumulations of dust and grease, and particularly from contact with lubricating oils, some of which permanently injure leather.

Leather belts must be well protected against water, and even moisture.

India-rubber is the proper substance for belts exposed to the weather, as it does not absorb moisture and stretch and decay.

Belts should be kept soft and pliable.

TIGHT BELTS.

Clamps with powerful screws are often used to put on belts with extreme tightness, and with most injurious strain upon the leather. They should be very judiciously used for horizontal belts, which should be allowed sufficient slackness to move with a loose, undulating vibration on the returning side, as a test that they have no more strain imposed than is necessary simply to transmit the power.

On this subject, the following from a New England cotton mill engineer of high reputation and large experience is entitled to careful consideration:

"I believe that three-quarters of the trouble experienced in broken pulleys, hot boxes, etc., can be traced to the fault of tight belts. The enormous and useless pressure thus put upon pulleys must in time break them, if they are made in any reasonable proportions, besides wearing out the whole outfit, and causing heating and consequent destruction of the bearings. If manufacturers realized how much this fault of tight belts cost them, in running their mills, probably they would 'wake up.'"

Below are some figures showing the power it takes in average modern mills with first-class shafting, to drive the shafting alone:

Mill		Horse power.		Horse power.		Per cent. of whole.
No. 1.	Whole load	=199	Shafting alone	= 51	or	25.6
" 2.	"	=472	"	=111.5	"	23.6
" 3.	"	=486	"	=134	"	27.5
" 4.	"	=677	"	=190	"	28.1
" 5.	"	=759	"	=172.6	"	22.7
" 6.	"	=235	"	= 84.8	"	36.1
" 7.	"	=670	"	=262.9	"	39.2
" 8.	"	=677	"	=182	"	26.8

These may be taken as a fair showing of the power that is required in many of our best (not worst) mills to drive shafting. It will be seen that the percentage is large—from 22 per cent. upwards. It is unreasonable to think that all that power is consumed by a legitimate amount of friction of bearings and belts. It is out of all reason, and I know of no cause for such a loss of power but *tight belts*. These, when there are hundreds or thousands in a mill, easily multiply the friction on the bearings and would account for the figures. Taking the cost of a H. P. at 35 lbs. of coal per day per H. P., and allowing 15 per cent. of the whole load as a reasonable

loss from friction. one can see that the cost of running tight belts is no inconsiderate one—to say nothing about the loss resulting from the shortened life of the entire equipment."

Rules for Calculating the Horse Power which can be Transmitted by Belting.

No rules can be given which will apply to all cases. Circumstances and conditions must and will modify them. Belts, for instance, for machines which are frequently stopped and started. and shifting belts, must be wider, to stand the wear and tear and to overcome the starting friction, than belts which run steadily and uninterruptedly. For belts, however, running under ordinarily favorable conditions, tbe rules given below may be regarded as safe and reliable.

The average thickness of single belts is 3-16 of an inch, and when made of good ox-hide, well tanned, their breaking strength per inch of width has been determined as follows:

In the solid leather, - -	675 lbs.
At the rivet holes of splices, -	362 "
At the lacing holes, - -	210 "

The safe working tension is assumed to be 45 lbs. per inch of width, which is equal to a velocity of about 60 square feet per minute per horse power, which is safe practice for single belts in good condition.

C=circumference, in inches of pulley.
D=diameter, " "
R=revolutions per minute, "
W=width of belt in inches.
H=horse power that can be transmitted by the belt.

Then:—To find the horse power a single belt can transmit, the size of the pulley and width of the belt being given:

$$H=\frac{C\times R\times W}{144\times 60} \quad \text{or,} \quad H=\frac{C\times R\times W}{8640} \quad \text{or,}$$

to simplify the process. substituting D for C, and dividing the constant 8640 by 3.1416, the proportion of circumference to diameter, the formula would be

$$H=\frac{D\times R\times W}{2750}$$

The transmitting efficiency of double belts of average thickness is to that of single belts as 10 is to 7; therefore, for double belts the formula would be:

$$H=\frac{D\times R\times W}{1925}$$

The horse power to be transmitted and the size of the pulley being given. to find the width of the belt required:

Single Belt.	Double Belt.
$W=\frac{H\times 2750}{D\times R}$	$W=\frac{H\times 1925}{D\times R}$

The horse power and width of belt being given, to find the diameter of pulley:

Single Belt.	Double Belt.
$D=\dfrac{H\times 2750}{R\times W}$	$D=\dfrac{H\times 1925}{R\times W}$

The horse power, diameter of the pulley and width of belt being given, to find the number of revolutions necessary:

Single Belt.	Double Belt.
$R=\dfrac{H\times 2750}{D\times W}$	$R=\dfrac{H\times 1925}{D\times W}$

In these rules it has been assumed that the belts are open, the pulleys of equal diameters, and the arc of contact is the semi-circumference. If, however, the pulleys are of different diameters and the arc of the contact is less than the semi-circumference, the rules must be modified accordingly.

If a belt is crossed and the arc of contact is greater than the semi-circumference, of course more power could be transmitted by the pulley; but only by increasing the tension so as to overtax the belt.

By multiplying the constant for the semi-circumference, by the ratios of frictions and pressure in the third column of the following table, the constant for every case likely to occur in practice, are obtained.

When the arc of contact of the smaller pulley is:

Degrees.		Circumference.	Ratio.	Constant. Sin. B.	Dou. B.
90	or,	¼ =.25	2.21	6080	4250
112½	"	5-16=.312	1.72	4730	3310
120	"	⅓ =.333	1.6	4400	3080
135	"	⅜ =.375	1.4	3850	2700
150	"	5-12=.417	1.24	3410	2390
157½	"	7-16=.437	1.17	3220	2250
180 to 270		½ =.5 to ¾ =.75	1.	2750	1925

The following tables, computed by the rules given above for semi-circumference, will be found useful and convenient.

When the diameters of the pulleys are different: Determine the arc of contact of the belt with the smaller pulley and divide the horse power given in the table by the ratio corresponding to the arc, as given in column three of preceding table.

TABLE

OF HORSE POWER WHICH MAY BE TRANSMITTED BY OPEN SINGLE BELTS TO PULLEYS RUNNING 100 REVOLUTIONS PER MINUTE. THE DIAMETERS OF THE DRIVING AND DRIVEN PULLEY BEING EQUAL.

The horse power of double belts is 10-7 of that given in the table.

Diam. of pulley.	Width of belt in inches.							
	2	2½	3	3½	4	4½	5	6
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
6	.44	.54	.65	.76	.87	.98	1.09	1.31
6½	.47	.59	.71	.83	.95	1.07	1.19	1.42
7	.51	.64	.76	.89	1.01	1.14	1.27	1.53
7½	.55	.68	.82	.95	1.09	1.23	1.36	1.64
8	.58	.73	.87	1.02	1.16	1.31	1.45	1.75
8½	.62	.77	.93	1.08	1.24	1.39	1.55	1.86
9	.65	.82	.98	1.15	1.31	1.48	1.64	1.97
9½	.69	.86	1.04	1.21	1.39	1.56	1.74	2.08
10	.73	.91	1.09	1.27	1.45	1.63	1.81	2.18
11	.8	1.	1.2	1.4	1.6	1.8	2.	2.4
12	.87	1.09	1.31	1.53	1.75	1.97	2.18	2.62
13	.95	1.18	1.42	1.65	1.89	2.12	2.36	2.83
14	1.02	1.27	1.52	1.77	2.02	2.27	2.53	3.05
15	1.09	1.36	1.64	1.91	2.19	2.46	2.73	3.29
16	1.16	1.45	1.74	2.03	2.32	2.61	2.91	3.48
17	1.24	1.55	1.85	2.16	2.47	2.78	3.09	3.70
18	1.31	1.64	1.96	2.29	2.62	2.95	3.27	3.92
19	1.39	1.73	2.07	2.42	2.76	3.11	3.45	4.14
20	1.45	1.82	2.18	2.55	2.91	3.27	3.64	4.36
21	1.52	1.91	2.29	2.67	3.05	3.44	3.82	4.58
22	1.6	2.	2.4	2.8	3.2	3.6	4.	4.8
23	1.67	2.09	2.51	2.93	3.35	3.75	4.18	5.02
	4	5	6	8	10	12	14	16
24	3.5	4.4	5.2	7.	8.7	10.5	12.2	14.
25	3.6	4.5	5.5	7.3	9.1	10.9	12.7	14.5
26	3.8	4.7	5.7	7.6	9.5	11.3	13.2	15.1
27	3.9	4.9	5.9	7.8	9.8	11.8	13.7	15.6
28	4.1	5.1	6.1	8.1	10.2	12.2	14.3	16.3
29	4.2	5.3	6.3	8.4	10.5	12.6	14.8	16.9
30	4.4	5.4	6.6	8.7	10.9	13.1	15.3	17.4
31	4.5	5.6	6.8	9.	11.3	13.5	15.8	18.
32	4.7	5.8	7.	9.3	11.6	14.	16.3	18.6
33	4.8	6.	7.2	9.6	12.	14.4	16.8	19.2
34	4.9	6.2	7.4	9.9	12.4	14.8	17.3	19.8
35	5.1	6.4	7.6	10.2	12.7	15.3	17.9	20.4
36	5.2	6.5	7.8	10.5	13.1	15.7	18.3	20.9
37	5.4	6.7	8.1	10.8	13.5	16.2	18.9	21.5
38	5.5	6.9	8.3	11.	13.8	16.6	19.3	22.1
39	5.7	7.1	8.5	11.3	14.2	17.	19.9	22.7
40	5.8	7.3	8.7	11.6	14.6	17.5	20.4	23.3
42	6.1	7.6	9.2	12.2	15.3	18.2	21.4	24.3
44	6.4	8.	9.6	12.8	16.	19.2	22.4	25.6

Table of Horse Power of Single Belts.—Continued.

Diam. of pulley.	Width of belt in inches.							
	4	5	6	8	10	12	14	16
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
46	6.7	8.4	10.	13.4	16.	20.1	23.4	26.8
48	7.	8.8	10.4	14.	17.4	21.	24.4	28.
50	7.2	9.	10.9	14.6	18.2	21.8	25.4	29.
54	7.8	9.8	11.8	15.6	19.6	23.6	26.4	31.2
60	8.8	10.8	13.1	17.4	21.8	26.2	30.6	34.8
66	9.6	12.	14.4	19.2	24.	28.8	33.6	38.4
72	10.4	13.	15.6	21.	26.2	31.4	36.6	41.8
78	11.4	14.2	17.	22.6	28.4	34.	39.8	45.4
84	12.2	15.2	19.4	24.4	30.6	36.4	42.8	48.6
	18	20	22	24	26	28	30	32
24	16	17	19	21	23	24	26	28
30	19	22	24	26	28	31	33	35
36	24	26	29	31	34	37	39	42
38	25	28	30	33	36	39	41	44
40	26	29	32	35	38	41	44	47
42	28	31	34	36	40	43	46	49
44	29	32	35	38	42	45	48	51
48	31	35	38	42	45	49	52	56
50	33	36	40	44	47	51	54	58
54	35	39	43	47	50	53	58	62
60	39	44	48	52	57	61	65	70
66	43	48	53	58	62	67	72	77
72	47	52	58	63	68	73	78	84
78	51	57	62	68	74	80	85	91
84	55	61	67	73	79	86	91	97
96	63	70	76	84	90	98	104	112
120	78	88	96	104	114	122	130	140
144	94	104	116	126	136	146	156	168

To Find the Length of Belt when Closely Rolled.

The sum of the diameter of the roll and the eye in inches, multiplied by the number of turns made by the belt, and this product multiplied by the decimal .1309, will equal length of the belt in feet.

To Find the Approximate Weight of Belts.

Multiply the length of the belt, in feet, by the width in inches and divide the product by 13 for single, and 8 for double belt.

GEARING.

In general, the term "gearing" is applied to all parts of machinery by which motion is transmitted; especially is it employed for wheels—whether friction or tooth. Tooth wheels are "in gear" when their teeth are engaged together; "out of gear" when separated.

Spur gears are wheels with the teeth or cogs ranged round the outer or inner surface of the rim, in the direction of radii from the centre,

and their action may be regarded as that of two cylinders rolling upon one another.

Bevel gears are wheels, the teeth of which are placed upon the outer periphery in a direction converging to the apex of a cone—and their action is similar to that of two cones rolling upon each other. When two bevel wheels of same diameter work together at an angle of 45° they are called "mitre wheels.

The teeth are called "teeth" when they are of one and the same piece as the body of the wheel, and "cogs" when they are of separate material. Wheels in whose rim "cogs" are inserted are called mortise wheels.

The straight line drawn from centre to centre of a pair of wheels is called the "line of centres."

The pitch-line, by which the size of a wheel is always given, represents as noted above, the touching of two cylinders rolling upon one another, and is the line or circle on which the 'pitch" of teeth is measured.

The pitch is distance between the centres of two adjacent teeth measured at the pitch-line.

PROPORTIONS FOR GEAR WHEELS.

P=pitch—in inches.
D=diameter of pitch circle, in inches.
a =height of tooth from pitch circle to face of tooth.
b =height of tooth from pitch circle to root of tooth.
c =thickness of tooth, in inches.
d =thickness of rim, in inches.
f =thickness of arms, if flat.
B=breadth of teeth, in inches.
N=number of teeth in the wheel.
R=revolutions of wheel per minute.
H=horse power that can be transmitted by the wheel.

$a=P\times 0.32$	$b=P\times 0.38$
$c=P\times 0.48$ when cast	$d=P\times 0.45$
$e=P\times 0.5$ when cut	$f=P\times 0.45$

Mortise wheels to be wider than iron wheels by $P\times 0.9$, and thickness of rim double that of iron wheels.

$$D=0.32\times P\times N.$$

$$H=\frac{P\times D\times B\times R}{550}$$

In calculating the speed of gears, multiply or divide, as the case may be, by the number of teeth (instead of diameter as for pulleys), and use the rule on page 75.

DIAMETRAL AND CIRCULAR PITCH.

Diametral pitch is the number of teeth to one inch of diameter of pitch line or circle.

Circular pitch is the distance from centre to centre of two adjacent teeth on the pitch-line.

No. 1 table shows the diametral pitches with the corresponding *circular pitches.*

No. 2 table shows the circular pitches with the corresponding diametral pitches.

TABLE NO. 1.		TABLE NO. 2.	
Diam. Pitch.	Circular Pitch.	Circular Pitch.	Diam. Pitch.
2	1.57	1¾ inch	1.79
2¼	1.39	1½ "	2.09
2½	1.25	1 7-16 "	2.18
2¾	1.14	1⅜ "	2.28
3	1.04	1 5-16 "	2.39
3½	.890	1¼ "	2.51
4	.785	1 3-16 "	2.66
5	.628	1⅛ "	2.79
6	.523	1 1-16 "	2.96
7	.448	1 "	3.14
8	.392	15-16 "	3.35
9	.350	⅞ "	3.59
10	.314	13-16 "	3.86
11	.280	¾ "	4.19
12	.261	11-16 "	4.57
14	.224	⅝ "	5.03
16	.196	9-16 "	5.58
18	.174	½ "	6.28
20	.157	7-16 "	7.18
22	.143	⅜ "	8.38
24	.130	5-16 "	10.06
26	.120	¼ "	12.56
28	.112	3-16 "	16.75

NOTES ON THE USE OF WIRE ROPE.

Two kinds of wire rope are manufactured. The most pliable variety contains 19 wires in the strand, and is generally used for hoisting and running rope.

For safe working load, allow 1-5 or 1-7 of the ultimate strength, according to speed, so as to get good wear from the rope. Wire rope is as pliable as new hemp rope of the same strength; but the greater the diameter of the sheaves the longer the wire rope will last.

Experience has proved that the wear increases with the speed. It is, therefore, better to increase the load than the speed. Wire rope must not be coiled or uncoiled like hemp or manilla—all untwisting or kinking must be avoided.

In no case should galvanized rope be used for running. One day's use scrapes off the zinc coating.—[Roebling.

TABLE OF STRAINS PRODUCED BY LOADS ON INCLINED PLANES.

Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.	Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.	Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.	Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.
ft. deg.		ft. deg.		ft. deg.		ft. deg.	
10=5½	112	50=26⅓	905	90=42	1347	130=52½	1592
20=11 1-5	404	60=31	1040	100=45	1419	140=54½	1633
30=16¾	586	70=35	1156	110=47¾	1487	150=56¼	1671
40=21 5-6	754	80=38⅔	1260	120=50¼	1544	160=58	1703

TABLE

OF TRANSMISSION AND HOISTING ROPES WITH NINETEEN WIRES TO THE STRAND—IRON.

Trade No.	Circumference in inches.	Diameter.	Weight p'r ft. in lbs. of rope with h'mp Cen.	Breaking strain in tons of 2000 lbs.	Proper work-load in tons of 2000 lbs.	Circumference of hemp r'pe of equal strength.	Min. size of drum or sh've in ft
1	6¾	2¼	7.80	74	15	15½	8
2	6	2	6.02	65	13	14½	7
3	5½	1¾	5.08	54	11	13	6½
4	5	1⅝	4.10	44	9	12	5
5	4⅜	1½	3.10	35	7	10¾	4½
6	4	1¼	2.44	27	5½	9½	4
7	3½	1⅛	1.95	20	4	8	3½
8	3⅛	1	1.50	16	3	7	3
9	2¾	⅞	1.14	11½	2½	6	2¾
10	2¼	¾	0.83	8.64	1¾	5	2½
10¼	2	⅝	0.65	5.13	1¼	4½	2
10½	1⅝	9-16	0.44	4.27	¾	4	1¾
10¾	1½	½	0.35	3.48	½	3½	1½

WROUGHT IRON, USUALLY ASSUMED.

A cubic foot, =480 lbs. | A square foot, 1 inch thick =40 lbs.
A bar 1 in. square, 1 ft. long= 3⅓ " | A bar 1 in. sq., 1 yd. long =10 "

To find the weight of cast iron balls when the diameter is given:
RULE.—Multiply the cube of the diameter by .1377.

To find the diameter of cast iron balls when the weight is given:
RULE:—Multiply the cube of the weight by 1.936.

To find the weight of a spherical shell:
RULE:—From the weight of a ball of the outer diameter subtract the weight of one of the inner diameters.

TO CONVERT THE WEIGHT OF

Wrought	iron	into cast	iron	×0.928
"	"	"	steel	×1.014
"	"	"	zinc	×0.918
"	"	"	brass	×1.082
"	"	"	copper	×1.144
"	"	"	lead	×1.468

DECIMAL APPROXIMATIONS USEFUL IN CALCULATIONS.

Cubic	ins.,	×.263 =	lbs. av.	cast iron.
"	"	×.281 =	"	wrought iron.
"	"	×.283 =	"	cast steel.
"	"	×.3225=	"	copper.
"	"	×.3037=	"	brass.
"	"	×.26 =	"	zinc.
"	"	×.4103=	"	lead.
"	"	×.2666=	"	tin.
"	"	×.4908=	"	mercury.

Cylin. ins.,	$\times$.2065=	lbs.	av.	cast iron.
"	"	$\times$.2168=	"	wrought iron.
"	"	$\times$.2223=	"	cast steel.
"	"	$\times$.2533=	"	copper.
"	"	$\times$.2385=	"	brass.
"	"	$\times$.2042=	"	zinc.
"	"	$\times$.3223=	"	lead.
"	"	$\times$.207 =	"	tin.
"	"	$\times$.3854=	"	mercury.

SPECIFIC GRAVITY.

Cast iron, - - - - -	average	7.21
Wrought iron, - - - -	"	7.78
Cast steel, - - - - -	"	7.85
Bessemer steel - - -	"	7.86

ight iron indicates impurity.
he heaviest steel contains least carbon.

TABLE

OF TRANSMISSION OF POWER BY WIRE ROPES.

howing necessary size and speed of wheels and rope to obtain any d amount of power [Roebling.

. of n ft.	No. of Revolut's.	Diam. of Rope.	Horse Power.	Diam. of Wh'l in ft.	No. of Revolut's.	Diam. of Rope.	Horse Power.
	80	3/8	3.3	10	80	11-16	58.4
	100	3/8	4.1		100	11-16	73.
	120	3/8	5.		120	11-16	87.6
	140	3/8	5.8		140	11-16	102.2
	80	7-16	6.9	11	80	11-16	75.5
	100	7-16	8.6		100	11-16	94.4
	120	7-16	10.3		120	11-16	113.3
	140	7-16	12.1		140	11-16	132.1
	80	1/2	10.7	12	80	3/4	99.3
	100	1/2	13.4		100	3/4	124.1
	120	1/2	16.1		120	3/4	148.9
	140	1/2	18.7		140	3/4	173.7
	80	9-16	16.9	13	80	3/4	122.6
	100	9-16	21.1		100	3/4	153.2
	120	9-16	25.3		120	3/4	183.9
	80	5/8	22.	14	80	7/8	148.
	100	5/8	27.5		100	7/8	185.
	120	5/8	33.		120	7/8	222.
	80	5/8	41.5	15	80	7/8	217.
	100	5/8	51.9		100	7/8	259.
	120	5/8	62.2		120	7/8	300.

PLATE IRON.

WEIGHT OF SUPERFICIAL FOOT.

Thickness in Inches.	Weight in Pounds.	Thcknessi in Inches.	Weight in Pounds.
1-32=.03725	1.25	5-16=.3125	12.58
1-16=.0625	2.519	⅜=.375	15.10
3-32=.0937	3.788	7-16=.4375	17.65
⅛=.125	5.054	½=.5	20.20
5-32=.1562	6.305	9-16=.5625	22.76
3-16=.1875	7.578	⅝=.625	25.16
7-32=.2187	8.19	¾=.75	30.20
¼=.25	10.09	⅞=.875	35.30
9-32=.2812	11.38	1=.1	40.40

To ascertain the weight of plate iron for rectangular sheets:

RULE:—Multiply the product of the length by breadth in inches, by one of the following decimals, according to thickness, and the product will be the weight required.

3-16	thick	×.0526
¼	"	×.07
5-16	"	×.0874
⅜	"	×.1048
7-16	"	×.1226
½	"	×.14
9-16	thick	×.158
⅝	"	×.1748
¾	"	×.2096
⅞	"	×.2452
1	"	×.28

FOR CIRCULAR SHEETS.

RULE:—Multiply the square of the diameter by one of the following decimals:

3-16	thick	×.0414
¼	"	×.055
5-16	"	×.0686
⅜	"	×.0823
7-16	"	×.0962
½	"	×.11
9-16	thick	×.124
⅝	"	×.1372
¾	"	×.1646
⅞	"	×.1924
1	"	×.22

RIVETS AND RIVETING.

Dr. Fairbairn estimates the strength of a joint, single riveted, according to the proportions of the following table at .56 that of one of the solid plates; and the strength of a double-riveted one at .7 that of one solid plate.

Rivet holes for important work should be drilled, not punched. There is no doubt that when the punching is carelessly done, the loss of strength is greater than that shown above.

Kirkaldy's experiments show that the shearing strain of steel rivets is one-fourth less than their tensile strength—and that the proportions of iron rivets are too small when steel rivets are used for steel plates.

Dr. Fairbairn gives, as reliable in practice, the following.

TABLE

FOR PROPORTIONING THE RIVETING FOR STEAM AND WATER-TIGHT JOINTS FOR IRON PLATES.

Thickness of each plate.	Diameter of Rivets.	Length of Rivets.	Cen. to cen. of Rivets.	Lap in single Riveting.	Lap in double Riveting.
Inches	Inches	Inches	Inches	Inches	Inches
3-16	⅜	⅞	1¼	1¼	21-16
¼	½	1⅛	1½	1½	2½
5-16	⅝	1⅜	1⅝	1⅞	31-16
⅜	¾	1⅝	1¾	2	3⅜
½	13-16	2¼	2	2¼	3¾
⅝	15-16	2¾	2½	2¼	4⅝
¾	1⅛	3¼	3	3¾	5½

These give diameter of rivet=1¾ thickness of one plate; length of rivet 2.6 diams.; distance from centre to centre 3 diams. For steel plates the proportions are too small.

WEIGHT OF CIRCULAR BOILER HEADS.

Diam. in Inches.	Thickness of Iron—Inches.						
	3-16	1-4	5-16	3-8	7-16	1-2	9-16
16	11	14	18	21	25	28	32
18	13	18	22	27	31	36	40
20	17	22	27	33	38	44	50
22	20	27	33	40	47	54	60
24	24	32	40	47	55	64	71
26	28	37	46	56	64	75	84
28	32	43	53	65	75	86	97
30	37	50	62	74	87	100	112
32	42	56	70	84	99	112	127
34	48	64	79	96	111	128	143
36	54	71	89	108	125	142	161
38	60	79	99	120	139	158	179
40	66	88	110	132	154	176	198
42	73	97	121	146	170	194	220
44	80	107	133	160	187	214	240
46	88	117	145	176	204	234	262
48	95	127	158	190	222	254	286
50	103	138	172	206	241	276	310
52	112	149	186	224	260	298	335
54	121	160	200	242	281	320	362
56	130	172	214	260	302	344	389
58	139	185	231	278	324	370	417
60	149	198	247	298	336	396	446

Kirkaldy says: The breaking strain of iron and puddled steel plates is greater in the direction in which they have been rolled than in the direction *of their breadth; but in* cast steel the reverse.

ROUND CAST IRON.—Weight, Lineal Foot.

Diam. Inches.	Weight. Pounds.	Diam. Inches.	Weight. Pounds.	Diam. Inches.	Weight. Pounds.	Diam. Inches.	Weight. Pounds.
1	2.45	4	39.27	7	120.26	11	296.98
1¼	3.84	4¼	44.33	7¼	129.01	11½	324.59
1½	5.52	4½	49.70	7½	138.06	12	353.43
1¾	7.52	4¾	55.38	7¾	147.42	13	414.79
2	9.82	5	61.36	8	157.08	14	481.06
2¼	12.43	5¼	67.65	8¼	167.05	15	552.23
2½	15.34	5½	74.25	8½	177.33	16	628.32
2¾	18.56	5¾	81.15	8¾	187.91	17	709.31
3	22.09	6	88.36	9	198.80	18	795.22
3¼	25.92	6¼	95.87	9½	221.51	20	981.75
3½	30.07	6½	103.70	10	245.44	22	1187.92
3¾	34.52	6¾	111.83	10½	270.60	24	1413.72

WROUGHT IRON WELDED TUBES.

For Steam, Gas, or Water.

One-eighth to 1 inch, inclusive, Butt-Welded. Tested to 300 lbs. per sq. inch, hydraulic pressure.

One and three-fourths inch and upwards, Lap-Welded. Tested to 500 lbs. per sq. inch, hydraulic pressure.

Nominal size.	Outside Diam. Standard.	Inside Diam. Standard.	Weight per foot. Lbs.	Threads to in. of screw.	Inside area sq. inches.
⅛	.40	.27	.24	27	.0572
¼	.54	.36	.42	18	.1018
⅜	.67	.49	.56	18	.1886
½	.84	.62	.85	14	.3019
¾	1.05	.82	1.12	14	.5281
1	1.31	1.04	1.67	11½	.8495
1¼	1.66	1.38	2.25	11½	1.4957
1½	1.90	1.61	2.69	11½	2.0358
2	2.37	2.06	3.66	11½	3.3329
2½	2.87	2.46	5.77	8	4.7529
3	3.50	3.06	7.54	8	7.3529
3½	4.00	3.54	9.05	8	9.8423
4	4.50	4.02	10.72	8	12.0924
4½	5.00	4.50	12.49	8	15.9043
5	5.56	5.04	14.56	8	19.9504
6	6.62	6.06	18.77	8	28.8426
7	7.62	7.02	23.41	8	38.7048
8	8.62	7.98	28.35	8	50.0146
9	9.68	9.00	34.07	8	63.6174
10	10.75	10.01	40.64	8	80.1186

RULE FOR STRENGTH OF CYLINDER BOILERS.

S=tensile strength of the iron. T=thickness of plate, in inches.
D=Diameter of shell, in inches. P=bursting pressure.

Then $P=\dfrac{T\times S}{D}\times 2$, and $T=\dfrac{P\times D}{S\times 2}$

Working strain allowed by U. S. laws for single-riveted boilers 1-6, and *for double-riveted* boilers 1-5 the bursting pressure.

TABLE

OF LAP-WELDED AMERICAN CHARCOAL IRON BOILER TUBES.

External diameter.	Internal diameter.	Thickness.	Length pipe per sq. ft. of outside sur'ce	Internal area.	External area.	Weight per foot.
In.	In.	In.	Feet.	In.	In.	Lbs.
1	.856	.072	3.816	0.575	0.785	0.7
1¼	1.106	.072	3.056	0.960	1.227	0.9
1½	1.334	.083	2.547	1.396	1.767	1.25
1¾	1.560	.095	2.183	1.911	2.405	1.66
2	1.804	.098	1.909	2.556	3.142	1.98
2¼	2.054	.098	1.698	3.314	3.976	2.23
2½	2.283	.109	1.528	4.094	4.939	2.75
2¾	2.533	.109	1.390	5.039	5.940	3.04
3	2.783	.109	1.273	6.083	7.069	3.33
3¼	3.012	.119	1.175	7.125	8.296	3.95
3½	3.262	.119	1.091	8.357	9.621	4.27
3¾	3.512	.119	1.018	9.687	11.045	4.59
4	3.741	.130	0.955	10.992	12.566	5.32
4½	4.241	.130	0.849	14.126	15.904	6.01
5	4.72	.140	0.764	17.497	19.635	7.22
6	5.699	.151	0.637	25.509	28.274	9.34

U. S. STANDARD SCREW THREADS.

Diam. of screw.	Thread per inch.	Diam. at root of thread.	Diam. of screw.	Thread per inch.	Diam. at root of thread.
¼	20	.185	2	4½	1.712
5-16	18	.240	2¼	4½	1.962
⅜	16	.294	2½	4	2.175
7-16	14	.344	2¾	4	2.425
½	13	.400	3	3½	2.628
9-16	12	.454	3¼	3½	2.878
⅝	11	.507	3½	3¼	3.100
¾	10	.620	3¾	3	3.317
⅞	9	.731	4	3	3.566
1	8	.837	4¼	2⅞	3.825
1⅛	7	.940	4½	2¾	4.027
1¼	7	1.065	4¾	2⅝	4.255
1⅜	6	1.160	5	2½	4.480
1½	6	1.284	5¼	2½	4.730
1⅝	5½	1.389	5½	2⅜	5.053
1¾	5	1.490	5¾	2⅜	5.203
1⅞	5	1.615	6	2¼	5.423

Angle of thread 60°. Flat at top and bottom ⅛ of pitch.

WHITWORTH'S GAS-THREADS.

Diameter in inches.	⅛	¼	⅜	½	¾	1 to 2
No. *thread to inch.*	28	19	19	14	14	11

FLUXES FOR SOLDERING OR WELDING.

Iron or steel........................Borax or sal-ammoniac.
Tinned iron........................Resin or chloride of zinc.
Copper and brass....................Sal-ammoniac or chloride of zinc.
Zinc................................Chloride of zinc.
Lead................................Tallow or resin.
Lead and tin pipes..................Resin and sweet oil.

BRAZING.

The edges filed or scraped clean and bright, covered with spelter and powdered borax, and exposed in a clear fire to a heat sufficient to melt the solder.

ALLOYS.

ALLOYS.	Tin.	Copper.	Zinc.	Antimony.	Lead.	Bismuth.
Brass, engine bearings	13	112	$\frac{1}{4}$	....	....	....
Tough brass, engine work	15	100	15	....	....	....
" for heavy bearings	25	160	5	....	....	....
Yellow brass, for turning	....	2	1	....	....	....
Flanges to stand brazing	....	32	1	....	1	....
Bell metal	5	16	....	....	....	....
Babbitt's metal	10	1	....	1	....	....
Brass, locomotive bearings	7	64	1	....	....	....
" for straps and glands	16	130	1	....	....	....
Muntz's sheathing	....	6	4	....	....	....
Metal to expand in cooling	....	....	....	2	9	1
Pewter	100	....	....	17	....	....
Spelter	....	1	1	....	....	....
Statuary bronze	2	90	5	....	2	....
Type metal....from	....	....	....	1	3	....
" "....to	....	....	....	1	7	....
SOLDERS.						
For lead	1	....	....	....	$1\frac{1}{2}$	....
" tin	1	....	....	....	2	....
" pewter	2	....	....	....	1	....
" brazing (hardest)	....	3	1	....	....	....
" " (hard)	....	1	1	....	....	....
" " (soft)	1	4	3	....	....	....
" " " ....or	2	....	....	1	....	....

STRENGTH OF IRON.

Tests by U. S. Ordnance department have determined:

1. That the strength and density of iron are greatly increased by its being continued in fusion, and by its being remelted.
2. That the transverse strength is augmented by rapid cooling in *small castings.*

3. That the tensile strength is increased by slow cooling in large ıasses.

Following is the table of Strength of Iron—Charooal Pig Iron.

	By whom tests were made.	No. of sam. tested.		Trans. strength.	Tensile strength.	Specific gravity.
				lbs. per sq. in.	lbs. per sq. in.	
⅄merican.	U. S. Ord. Dept.	56	Mean	9,409	27,232	7,302
			Least	8,014	22,402	7,163
			Great.	10,717	31,027	7,402
ʗnglish.	Brit. Ord. Dept.	51	Mean	7,102	23,257	7,140
			Least	5,538	17,958	7,052
			Great.	9,120	28,960	7,259

The mean strength of American wrought iron is 55,900 lbs.; English 3,900. Ultimate extension of wrought iron is 600th part of its length. he working strain is from 1-6 to ¼ the mean strength.

Resistance to flexure acting evenly over the surface, equals one-half ıe tensile strength. Bars of wrought iron will expand or contract 51200th of their length for each degree of heat. With range of tempera- ıre of this country (=20 to+120°)=140°, will expand or contract 1080th art of its length, equal to a force of 20,740 lbs., or 9¼ tons per square inch f section. Tensile strength increases, in from 1 to 6 reheatings and ›llings, from 43,904 lbs. to 60,824 lbs.; in from 6 to 12, is reduced again › 43,904.

To Test Quality of Iron.

If fracture gives long silky fibres of leaden-gray hue, fibres cohering ıd twisting together before breaking, may be considered a tough, soft on. A medium even grain mixed with fibres, a good sign. A short, lackish fibre indicates badly refined iron. A very fine grain denotes a ard, steely iron, apt to be cold short, hard to work with the file. Coarse rain with brilliant crystallized fracture, yellow or brown spots, denotes a rittle iron, cold short, working easily when heated, welds easily. Cracks ı the edge of bars, sign of hot, short iron. Good iron is readily heated, ›ft under the hammer, and throws out but few sparks.

All iron contains more or less carbon—the hardest the most.

Note on Forgings.

Iron, while heating, if exposed to air, will oxidize; while at white heat in contact with coal, will carbonize, or become steely. Iron should be eated as rapidly as possible.

Steel.

Steel is a compound of iron and carbon, varying in proportion of 0.5 er cent. to 5 per cent. of carbon. Specific gravity 7.8; tensile strength, 20,000 lbs. per sq. inch. Ordinary steel is carbon steel, but steely com- ounds of iron have been produced which have the same general proper- es as ordinary steel, the carbon of which is replaced by other chemical .ements.

Foreign Substances in Iron and Steel.

Silicon is generally excluded as slag, its presence makes iron hard and rittle; but up to .08 per cent, it will do no harm,provided .3 of manganese , present with it.

Sulphur makes iron and steel "red-short."

Phosphorus. .5 to .8 per cent. is sufficient to produce cold-shortness in iron; in steel, phosphorus to an extent of .2 per cent. does not affect the working or hammering of steel.

Manganese. .5 per cent. is sufficient to make iron cold-short; it is valuable in iron to be converted into steel.

Arsenic produces red-shortness in iron—but is valuable in chilling; it increases the hardness in steel a the expense of the toughness.

Copper renders steel red-short.

Tungsten renders steel hard and tenacious.

Vanadium improves the ductility of iron for wire-drawing.

Carbon. .25 per cent. gives malleable iron; .5 per cent. gives steel; 1.75 gives the limit of welding steel; 20 gives the lowest limit of cast iron.

To Test Steel and Iron.

Nitric acid will produce a black spot on steel; the darker the spot the harder the steel. Iron, on the contrary, remains bright if touched with nitric acid. Good steel in its soft state has a curved fracture and a uniform gray lustre; in its hard state a dull, silvery, uniform white. Cracks, threads, or sparkling particles, denote bad quality.

Good steel will not bear a white heat without falling to pieces, and will crumble under the hammer at a bright red heat, while at a middling heat it may be drawn out under the hammer to a fine point.

Tempering Steel.

Color.	Purpose.	Tem. Fah.	All'y whose fusing point is same tem. Tin.		Lead.
Light straw	Turning tools for metal.	430°	1	to	1¾
Dark straw	Wood tools, taps and dies.	470°	1	to	2½
Brown yellow	Hatchets, Chip'g chis.	500°	1	to	4¾
Dark purple	Springs, etc.	550°	1	to	12

NOTES ON THE WORKING OF STEEL.

Extract from a Lecture read before the Engineers Society of Western Pennsylvania, by William Metcalf, C. E.

1. Good soft heat is safe to use if steel be immediately and thoroughly worked.

It is a fact that good steel will endure more pounding than any iron.

2. If steel be left long in the fire it will lose its steely nature and grain and partake of the nature of cast iron.

Steel should never be kept hot any longer than is necessary to the work to be done.

3. Steel is entirely mercurial under the action of heat, and a careful study of the table will show that there must of necessity be an injurious internal strain created, whenever two or more parts of the same piece are *subjected to* different temperatures.

4. It follows that when steel has been subjected to heat not absolutely uniform over the whole mass, careful annealing should be resorted to.

5. As the change of volume due to a degree of heat increases directly and rapidly with the quantity of carbon present, therefore high steel is more liable to dangerous internal strains than low steel, and great care should be exercised in the use of high steel.

6. Hot steel should always be put in a perfectly dry place of even temperature while cooling. A wet place in the floor might be sufficient to cause serious injury.

7. Never let any one fool you with the statement that his steel possesses a peculiar property which enables it to be "restored" after being "burned;" no more should you waste any money on nostrums for restoring burned steel.

We have shown how to restore "over-heated" steel.

For "burned" steel, which is oxidized steel, there is only one way of restoration, and that is through the knobbling fire or the blast furnace.

"Over-heating" and "restoring" should only be allowable for purposes of experiment. The process is one of disintegration, and is always injurious.

8. Be careful not to overdo the annealing process; if carried too far it does great harm, and it is one of the commonest modes of destruction which the steel-maker meets in his daily troubles.

It is hard to induce the average worker in steel to believe that very little annealing is necessary, and that a very little is really more efficacious than a great deal.

Mr. Kirkaldy's experiments show conclusively:—

1st. That the breaking strain of iron and steel does not (as hitherto assumed) indicate the quality. A high breaking strain may be due to hard, unyielding character, or a low one may be due to extreme softness. The contraction of area at the fracture forms an essential element in estimating the quality.

2d. Iron when fractured suddenly produces a crystalline fracture; but if gradually, a fibrous fracture. This accounts for the anomaly in the supposed change of iron from a fibrous to a crystalline character. Sudden shoulders which prevent a regular elongation of fibre cause a sudden snap.

3d. Strength of steel is reduced by being hardened in water; but both its hardness and toughness are increased by being hardened in oil. Iron heated, and suddenly cooled in water, is hardened, and the breaking strain (if gradually applied) is increased, but it is more likely to snap suddenly. It is softened and its breaking strain reduced if heated and allowed to cool gradually. Iron if brought to a white heat, is injured if it be not at the same time hammered or rolled. Case-hardening bolts weakens them.

WORKSHOP RECEIPTS.

The following useful receipts were taken in part from F. W. Bacon, on the "Indicator:"

"It is bad practice to pack the joints of steam chests, cylinder heads, etc., with rubber; in fact any joint exposed to heat, as the sulphur used in vulcanizing, disintegrates the cast iron and inevitably corrodes the bolts in time. It may be tolerated in the manhole of the boiler."

A good manilla paper is the best thing we have found for good surfaces where the joints are thin. Printers' cardboard is most excellent where the surfaces are a little uneven, and will last longer than anything.

we have ever used. The cardboard is just as good after the printers have used it.

A good cement is made by taking a quantity of pure red lead, (depending on the amount of putty required), put it in an iron mortar, or on a block, or a thick plate of iron. Put a quantity of pure white lead ground in oil, knead them together until you make a thick putty, then pound it; the more you pound it the softer it will become; roll in red lead and pound again, repeat the operation, adding red lead and pounding until the mass becomes a good stiff putty, the more pounding the better. In applying to flange or joint, it is well to put a thin grummet, or fine cord around the orifice of the pipe or joint, to prevent the cement from going into the pipe; when the bolts are to be screwed up the joints should be close together.

Another, to be used when the flanges are not faced: Make the mass rather soft and add cast iron borings; pound it thoroughly until it is sufficiently soft to spread.

Both of the above are the most durable cements known to the engineer. They will resist fire and set in water.

BELT DRESSING.—A good dressing for leather belts is: One part of beef kidney tallow and two parts of castor oil well mixed and applied warm. It will be well to moisten the belt slightly with warm (not hot) water before applying it. No rats or other vermin will touch it after one application.

Value of Pea and Dust Coal, as compared with lump of good merchantable quality, with a blast induced by "Hancock's Steam Blower."

2,000 lbs. of pea and dust, the screenings from the coal yards, have been found equal to 1,600 lbs. of lump. This is a result of several weeks' trial with the same engine and boiler doing the same work.

Value of Cumberland coal as compared with anthracite. Two tons (4,000 lbs.,) of anthracite furnished steam for an engine seven days. The same amount of Cumberland served the same engine, everything else the same, eight days. This experiment was continued with alternate changes for two months.

Boiler, locomotive type, with natural draft.

This is confirmed by the author, who has found in his experience a saving of 10% to 15% in favor of Clearfield or George's Creek bituminous coal.

TO CLEAN GAUGE GLASSES.—Gauge glasses, when required to be cleaned, should have a wooden swab-stick. A metallic one will cause the tubes to fall to pieces inevitably, and sometimes immediately.

When there are indications of an extraordinary corrosion of the steam boiler and its fittings where the gauge-cocks and valves leak. Acid is suspected. Test it by putting into a sample of the water a strip of litmus paper; if acid is present, the purple paper will be changed to red.

The writer has found two cases where the wells that supplied steam-boilers were poisoned by the *spent pickle* finding its way into the wells, thence to the boilers, and was detected as above. The iron (sulphate) was so abundant, when a proper quantity of tannin was put in, it formed a sufficient ink so that the report of the examination was written with it.—[F. W. Bacon.

When water scales the boiler. Lime is suspected. TEST.—Into a tumbler containing the suspected water put 8 or 10 grains of oxalic acid; if lime is present, the water will become milky, and after standing quiet awhile, the lime will be precipitated (oxalate of lime).

Should the precipitate not show itself, add a little ammonia, which is a more delicate test. If no precipitate is shown, it is not lime that forms the scale.—[F. W. B.

STRONG CEMENT for leather belts and aprons:—1½ pints of soft water, ¾ lbs. best Frost glue, 2 oz. No. 1 white glue, 1 oz. American isinglass. Cook until it is all dissolved and fit to use, then add 2 oz. dry powdered white lead, white of egg beaten to froth; stir thoroughly, and remove from fire and allow it to cool 10 minutes, then add and stir in ½ oz. of bleached shellac cut in 4 oz. of alcohol and 1 oz. of ether.

COMMON CEMENT for leather belts:—Take of good glue and isinglass equal parts, and place in a glue pot, add water to cover the whole, soak 10 hours and bring to boiling heat, add pure tannin till the mass becomes roapy, add the whites of eggs sufficient, while warm. Buff off the leather where it is to be cemented, rub the surfaces of the joints solidly together, let it dry a few hours, and it is ready for use. If properly put together no rivets are needed as the cement is as strong as the leather.

CEMENT for leather lagging or iron pulleys:—4 parts strong glue, 1 part pitch, put on hot. Draw leather very tight with a good leverage or tackle. Clean surface of pulley with benzine.

CEMENT for holes in iron, brass, or copper kettles:—Equal parts of litharge and glycerine, made into a stiff putty. Fill the hole and round it over on each side, let it stand until hard. Water can be boiled in the kettle without leaking.

PARTING SAND.—Burnt sand scraped from the surface of castings.

LOAM.—Mixture of brick, clay and old foundry sand.

BLACKENING FOR MOULDS.—Charcoal powder; or, in some instances fine coal dust.

BLACK WASH.—Charcoal, plumbago and size.

MIXTURE FOR WELDING STEEL.—1 sal-ammoniac, 10 borax. Pounded together, and fused until clear, when it is poured out, and, after cooling, reduced to powder.

RUST-JOINT CEMENT. (Quickly setting.)—1 sal-ammoniac in powder (by weight), 2 flour of sulphur, 80 iron borings, made to a paste with water.

RUST-JOINT. (Slowly setting.)—2 sal-ammoniac, 1 flour of sulphur, 200 iron borings. The latter cement is the best if the joint is not required for immediate use.

RED LEAD CEMENT FOR FACE-JOINTS.—1 of white lead, 1 of red lead mixed with linseed oil to the proper consistency.

CASE-HARDENING.—Place horn, hoof, bone dust, or shreds of leather, together with the article to be case-hardened, in an iron box subject to a blood-red heat, then immerse the article in cold water.

CASE-HARDENING WITH PRUSSIATE OF POTASH.—Heat the article after polishing to a bright red, rub the surface over with prussiate of potash; allow it to cool to a dull red, and immerse it in water.

CASE-HARDENING MIXTURE.—3 prussiate of potash, 1 sal-ammoniac, or, 1 prussiate potash, 2 sal-ammoniac, 2 bone dust.

GLUE TO RESIST MOISTURE.—1 pound of glue melted in 2 quarts of skim-milk.

MARINE GLUE.—1 of India-rubber. 12 of mineral naphtha or coal tar. Heat gently, mix, and add 20 of powdered shellac. Pour out on a slab to cool. When used, to be heated to about 250°.

GLUE CEMENT TO RESIST MOISTURE.—1 glue. 1 black resin. ¼ red ochre. Mixed with least possible quantity of water. Or, 4 of glue. or 1 oxide of iron. 1 of boiled oil (by weight).

TO REMOVE RUST FROM STEEL.—Steel which has been rusted can be cleaned by brushing with a paste compound of ½ oz. cyanide potassium. ½ oz. castile soap. 1 oz. whiting. and water sufficient to form a paste. The steel should be washed with a solution of ½ oz. cyanide potassium in 2 oz. water.

TO PRESERVE STEEL FROM RUST.—1 caoutchouc. 16 turpentine. Dissolve with a gentle heat. then add 8 parts boiled oil. Mix by bringing them to the heat of boiling water; apply to the steel with a brush, in the way of varnish. It may be removed with turpentine.

TO CLEAN BRASS.—1 Roche alum and 16 water. Mix. The article to be cleaned must be made warm, then rubbed with the above mixture. and finished with fine tripoli.

DIFFERENT COLORS OF IRON, CAUSED BY HEAT.

Deg. Cen.	Deg. Fah.	
261 370	502 680	Violet, purple and dull blue. Between 261° C to 370° C it passes to bright blue, sea green, and then disappears.
500	932	Commences to be covered with a light coating of oxide: becomes a deal more impressible to the hammer, and can be twisted with ease.
525	977	Becomes nascent red.
700	1292	Sombre red.
800	1472	Nascent cherry.
900	1657	Cherry.
1000	1832	Bright cherry.
1100	2012	Dull orange.
1200	2192	Bright orange.
1300	2372	White.
1400	2552	Brilliant white-welding heat.
1500 1600	2732 2912	Dazzling white.

MELTING POINT OF METALS.

Platinum,	3080°	Fah.	(Pouillet)	Silver,	1832°	Fah.	(Pouillet)
Wrought iron,	2822	"	"	Antimony,	842	"	(I. L. Bell)
Steel,	2462	"	"	Zinc,	782	"	"
Cast iron (Gray)	2210	"	"	Lead,	620	"	"
Gold,	*2192*	"	"	Tin,	475	"	"

EXPANSION OF METALS. (Faraday.)

	At 212°	Ex. per deg. Fah.
Brass	1.0019062	.0000106
Copper	1.001745	.0000097
Cast Iron	1.0011112	.0000062
Steel	1.0011899	.0000066
Wrought Iron	1.0012575	.000007
Tin	1.002	.0000111
Zinc	1.002942	.0000163

The length of the bar at 32°=1.

Almost all bodies expand in equal proportion for each degree between freezing and boiling.

To ascertain the expansion of a body: Multiply the dimension of the body by the number of degrees of increase of temperature and then by the expansion per degree.

EXAMPLE:—Required the expansion of a steel rail 30 feet long, with an increase of temperature of 100°:

$$30 \times 100 = 3000 \times .0000066 = .0198 \text{ foot} = \tfrac{1}{4} \text{ inch.}$$

DECREASE OF STRENGTH OF WROUGHT IRON AT HIGH TEMPERATURE.

(Experiments by W. Johnson and Benj. Reeves, Com. Franklin Ins., 1839.)

Temperature.		Decrease per ct. of max. tena'y.	Temperature.		Decrease per ct. of max. tena'y.
Cen.	Fah.		Cen.	Fah.	
271°	520°	.0738	500°	932°	.3324
313		.0899	554		.4478
332	630	.1047	599		.5514
350		.1155	624	1154	.6
389	732	.1491	669		.6622
440		.2010	708	1306	.7001

STRENGTH OF MANILA AND HEMP ROPES.

"The strength of rope is very irregular, much depending on the quality of the fibre used and the solidity in which the rope is put together. For instance, 3¼ inch circumference soft-laid rope will not measure over 3 inch circumference hard-laid.

"Our tests of the various makes of rope from the manila fibre, show about the following average maximum strength:

3 inch	circumference,	soft-laid.	7,300 lbs.
3 "	"	medium-laid,	8,000 "
3 "	"	hard-laid,	9,000 "

"We find it a safe rule, up to 5-inch circumference, to multiply the square of the circumference by 8 and the product will be the number of net 100 lbs. required to break the rope.

"From the tests we have from the U. S. Govt. Cordage works, of the breaking strength of tarred Russia and American hemp cordage, we would say that the above rule will apply to tarred cordage as well as to manila.

"Where *blocks and falls* are used it is a safe rule to put rope in use at

⅛ its breaking strain; and that in two double-blocks of suitable size. Say, for instance, it is desired to raise regularly 1000 lbs.—two double 8-inch blocks reeved with 3-inch circumference manila rope should be used.

"For direct pulls on a single rope, say up to 5-inch circumference, we find it safe where in constant use to put it at work at only 1-20 its breaking strain. For instance, on a hoisting machine in a warehouse where hoists of 1000 to 1500 lbs. are made (the latter occasionally), we place for the hook rope 5-in. cir. manila rope. This gives durability, and allows for wear and tear.

"Of course wear and tear and the want of proper care must be allowed for as rope grows old. The best rope made will be quickly destroyed by allowing it to become wet and then putting it in a damp cellar or room where there is no circulation of air."

WEIGHT AND STRENGTH OF SHORT-LINK IRON CHAINS.

Since each link consists of two thicknesses of bar, it might be supposed that a chain would possess double the strength of a single bar, but the strength of the bar becomes reduced about 3-10 by being formed into links; so that the chain really has but about 7-10 of the strength of two bars. As a thick bar of iron will not sustain as heavy a load in proportion as a thinner one, so of course, large chains are proportionately weaker than smaller ones. In the following table, 20 tons (gross) per sq. inch is assumed as the average breaking strain of a single straight bar of ordinary rolled iron 1 inch in diameter; 19 tons, from 1 to 2 in. dia.; and 18 tons from 2 to 3 in. dia. Deducting 3-10 from each of these, we have as the breaking strain of the two bars composing each link as follows: 14 tons per sq. inch, up to 1 inch diameter; 13.3 tons, from 1 to 2 in.; and 12.6 tons from 2 to 3 in. dia., and upon these assumptions the table is based.—[Trautwine.

TABLE

OF WEIGHTS AND STRENGTH OF SHORT-LINK IRON CHAINS.

Dia. of iron.	Av. wt. per ft.	Break'g. strain	Dia. of iron.	Av. wt. per ft.	Break'g. strain
Ins.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.
3-16	.42	1,731	1	10.	49,280
¼	.91	3,069	1-16	11.3	52,790
5-16	1.22	4,794	⅛	12.5	59,226
⅜	1.5	6,922	3-16	14.	65,960
7-16	2.	9,408	¼	15.5	73,114
½	2.5	12.320	⅜	18.5	88,301
9-16	3.2	15,590	½	22.	105,280
⅝	4.1	19,219	⅝	25.5	123,514
11-16	5.	23,274	¾	29.5	143,293
¾	5.8	27.687	⅞	33.5	164,505
13-16	6.6	32,307	2	38.	187,152
⅞	7.7	37,632	¼	48.5	224,448
15-16	8.9	43.277	½	60.0	277.088

TO CRUSH AN INCH CUBE OF

Wrought iron, requires .... 16 tons.
Cast iron, " .... 49 "
Steel, " .... 100 "

TABLE.

SAFE LOAD FOR HOLLOW CAST IRON PILLARS. (Tons, 2240 lbs.)

External diameter in inches	Thickness of metal=½ inch. Length in Feet.				
	8	10	12	14	16
3	4.0	3.2	2.3	1.8	1.4
3½	5.9	5.1	3.6	2.7	2.3
4	8.1	6.1	4.7	3.6	3.4
4½	10.6	8.1	6.5	5.0	4.4
5	13.3	10.4	8.3	6.7	5.4
5½	15.3	12.9	10.5	8.5	7.0
6	19.0	15.5	12.7	9.5	8.7
	Thickness of metal=⅝ inch.				
3	4.7	3.5	2.6	2.0	1.6
3½	7.1	5.3	4.2	3.2	2.5
4	9.2	7.3	5.6	4.4	3.9
4½	12.8	9.9	7.7	6.1	5.5
5	16.1	12.7	9.1	8.1	7.0
5½	18.7	15.7	12.8	10.4	8.8
6	23.2	19.0	15.6	12.8	10.6
6½	26.9	22.4	18.7	15.2	13.0
7	30.7	26.0	21.9	18.5	15.6
	Thickness of metal=¾ inch.				
3	5.4	3.8	2.8	2.2	1.7
3½	8.1	6.2	4.4	3.5	2.6
4	11.3	8.5	6.5	4.8	3.8
4½	14 9	11.5	8.9	7.2	6.0
5	18.8	14.8	11.7	9.0	7.7
5½	21.8	18.4	14.9	12.1	10.2
6	27.2	22.3	18.3	15.0	12.5
6½	31.6	26.3	21.9	17.8	15.3
7	36.1	30.6	25.8	21.7	18.4
	Thickness of metal=1 inch.				
4	13.9	10.4	8.0	6.4	4.8
4½	18.5	14.3	11.1	8.8	7.1
5	23.6	18.6	14.8	11.9	9.6
5½	27.6	23.2	18.9	15.3	12.7
6	34.5	28.3	23.2	19.1	15.9
6½	40.3	33.6	28.0	22.8	19.6
7	46.2	39.1	33.0	27.8	23.6
7½	52.2	44.9	38.3	32.6	27.9
8	58.3	50.7	43.8	37.7	32.5
8½	64.3	56.5	49.4	42.9	37.3
9	70.5	62.7	55.3	48.1	42.3
Diam. in In.	STRENGTH OF CAST IRON SOLID PILLARS.				
2	1.4	1.0	.7	.50	.44
2¼	2.1	1.5	1.0	.83	.66
2½	2.9	2.1	1.6	1.21	.95
2¾	4.0	3.0	2.2	1.72	1.35
3	6.0	4.0	3.0	2.30	1.84

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

USEFUL NUMBERS.

Linear feet	× .00019	=	miles.
" yards	× .000568	=	" "
Square inches	× .007	=	square feet.
" feet	× .111	=	" yards.
" yards	× .0002067	=	acres.
Acres	× 4840	=	square yards.
Cubic inches	× .00058	=	cubic feet.
" feet	× .03704	=	" yards.
Circular inches	× .00546	=	square feet.
Cylindrical inches	× .0004546	=	cubic feet.
" feet	× .02909	=	" yards.
Links	× .22	=	yards.
"	× .66	=	feet.
Feet	× 1.5	=	links.
Width in chains	× 8.	=	acres per mile.
183.346 circular inches		=	1 square foot.
2200 cylindrical inches		=	1 cubic foot.
Cubic feet	× 7.48	=	U. S. gallons.
" inches	× .004329	=	" "
Cylindrical feet	× 5.874	=	" "
" inches	× .0034	=	" "
U. S. gallons	× .13367	=	cubic feet.
" "	× 231.	=	" inches.
Cubic feet	× .8036	=	U. S. bushel.
" inches	× .000466	=	" "
U. S. bushels	× .0495	=	cubic yards.
" "	× 1.2446	=	" feet.
" "	× 2150.42	=	" inches.
Cylindrical feet of water	× 6.	=	U. S. gallons.
Pounds avoirdupois	× .009	=	cwt. (112.)
" "	× .00045	=	tons (2240).
Cubic feet of water	× 62.5	=	lbs. avoirdupois.
" ins. "	× .03617	=	" "
Cylindrical feet of water	× 49.1	=	" "
" ins. "	× .02842	=	" "
13.44 U. S. gallons of water		=	1 cwt.
268.8 " " "		=	1 ton.
1.8 cubic feet of water		=	1 cwt.
35.88 " " "		=	1 ton.
Column of water 12 ins. high, 1 inch diameter		=	.341 lbs.

CIRCUMFERENCE, AREAS, SQUARES, ETC., OF CIRCLES.

Advancing by 16ths. 8ths. and 4ths.—1 to 9¾.

Dia. or No.	Circum.	Area.	Square.	Cube.	Sq. Root.	Cube root.
1	3.14	.7854	1.	1.	1.	1.
1-16	3.34	.886	1.13	1.19	1.031	1.020
⅛	3.53	.994	1.27	1.49	1.060	1·040
3-16	3.73	1.107	1.41	1.67	1.089	1.059
¼	3.93	1.227	1.56	1.95	1.118	1.077
5-16	4.12	1.358	1.72	2.26	1.146	1.095
⅜	4.32	1.485	1.89	2.60	1.173	1.112
7-16	4.52	1.623	2.07	2.97	1.199	1.129
½	4.71	1.767	2.25	3 38	1.225	1.145
9-16	4.91	1.917	2.44	3.82	1.250	1.161
⅝	5.11	2.074	2.64	4.29	1.275	1.176
11-16	5.30	2.236	2.85	4.80	1.299	1.191
¾	5.50	2.405	3.06	5.36	1.323	1.205
13-16	5.69	2.580	3.29	5.95	1.346	1.219
⅞	5.89	2.761	3.52	6.59	1.369	1.233
15-16	6.09	2.948	3.75	7.27	1.392	1.247
2	6.28	3.142	4.	8.	1.414	1.260
1-16	6.48	3.341	4.25	8.77	1.436	1.273
⅛	6.68	3.547	4.52	9.59	1.458	1.286
3-16	6.87	3.758	4.78	10.47	1.479	1.298
¼	7.07	3.976	5.03	11.39	1.5	1.310
5-16	7.26	4.200	5.35	12.36	1.521	1.322
⅜	7.46	4.430	5.64	13.40	1.541	1.334
7-16	7.66	4.666	5.94	14.48	1.561	1.346
½	7.85	4.900	6.25	15.63	1.581	1.358
9-16	8.05	5.157	6.57	16.83	1.600	1.369
⅝	8.25	5.412	6.89	18.08	1.620	1.380
11-16	8.44	5.673	7.22	19.41	1.639	1.391
¾	8.64	5.940	7.56	20.79	1.658	1.402
13-16	8.84	6.213	7.91	22.25	1.677	1.412
⅞	9.03	6.492	8.27	23.76	1.695	1.422
15-16	9.23	6.777	8.63	25.34	1.714	1.432
3	9.42	7.07	9.	27.	1.732	1.442
⅛	9.82	7.67	9.77	30.52	1.768	1.462
¼	10.21	8.30	10.56	34.32	1.803	1.482
⅜	10.60	8.95	11.39	38.44	1.837	1.5
½	11.00	9.62	12.25	42.88	1.871	1.518
⅝	11.39	10.32	13.14	47.63	1.904	1.535
¾	11.78	11.05	14.06	52.73	1.936	1.553
⅞	12.17	11.79	15.02	58.17	1.968	1.570
4	12.57	12.57	16.	64.	2..	1.587
¼	13.35	14.19	18.06	76.78	2 061	1.619
½	14.14	15.90	20.25	91.13	2.121	1.651
¾	14.92	17.72	22.56	107.16	2.179	1.681
5	15.71	19.63	25.	125.	2.236	1.710
¼	16.49	21.64	27.56	144.70	2.291	1.738
½	17.28	23.76	30.25	166.37	2.345	1.765
¾	18.06	25.97	33.06	190.11	2.398	1.792

CIRCUMFERENCES, ETC. Continued.

Advancing by 16ths, 8ths, 4ths.—1 to 9¾.

Dia. or No.	Circum.	Area.	Square.	Cube.	Square root.	Cube root.
6	18.85	28.29	36.	216.	2.449	1.817
¼	19.64	30.68	39.06	244.14	2.5	1.832
½	20.42	33.18	42.25	274.63	2.550	1.866
¾	21.21	35.78	45.56	307.55	2.599	1.890
7	21.99	38.48	49.	343.	2.646	1.913
¼	22.78	41.28	52.56	381.08	2.692	1.935
½	23.56	44.18	56.25	421.88	2.739	1.957
¾	24.35	47.17	60.06	465.48	2.784	1.979
8	25.13	50.26	64.	512.	2.828	2.
¼	25.92	53.46	68.06	561.52	2.872	2.021
½	26.70	56.75	72.25	614.12	2.915	2.041
¾	27.49	60.13	76.56	669.92	2.958	2.061
9	28.27	63.62	81.	729.	3.	2.080
¼	29.06	67.20	85.56	791.45	3.041	2.098
½	29.85	70.88	90.25	857.37	3.082	2.118
¾	30.63	74.66	95.06	926.86	3.122	2.136

CIRCUMFERENCES, AREAS, SQUARES, CUBES, SQUARE AND CUBE ROOTS.—10 to 85.

NOTE. To find the fourth power (or biquadrate) of a number, multiply the square by the square.

To find the 4th root, extract the square root in succession.

Dia. or No.	Circum.	Area.	Square.	Cube.	Square root.	Cube root.
10	31.41	78.54	100	1000	3.162	2.154
11	34.55	95.03	121	1331	3.317	2.224
12	37.69	113.0	144	1728	3.464	2.289
13	40.84	132.7	169	2197	3.606	2.351
14	43.98	153.9	196	2744	3.742	2.410
15	47.12	176.7	225	3375	3.873	2.466
16	50.26	201.0	256	4096	4.	2.520
17	53.40	226.9	289	4913	4.123	2.571
18	56.54	254.4	324	5832	4.243	2.621
19	59.69	283.5	361	6859	4.359	2.668
20	62.83	314.1	400	8000	4.472	2.714
21	65.97	346.3	441	9261	4.583	2.759
22	69.11	380.1	484	10648	4.690	2.802
23	72.25	415.4	529	12167	4.796	2.844
24	75.39	452.3	576	13824	4.899	2.885
25	78.54	490.8	625	15625	5.	2.924
26	81.68	530.9	676	17576	5.099	2.963
27	84.82	572.5	729	19683	5.196	3.
28	87.96	615.7	784	21952	5.292	3.037
29	91.10	660.5	841	24389	5.385	3.072
30	94.24	706.8	900	27000	5.477	3.107
31	97.39	754.8	961	29791	5.568	3.14
32	*100.5*	804.2	1024	32768	5.657	3.17
33	*103.7*	855.3	1089	35937	5.745	3.20

CIRCUMFERENCES, AREAS. ETC. 10 to 85.—Continued.

Dia. or No.	Circum.	Area.	Square.	Cube.	Square root.	Cube root.
34	106.8	907.9	1156	39304	5.831	3.240
35	110.	962.1	1225	42875	5.916	3.271
36	113.1	1017.9	1296	46656	6.	3.302
37	116.2	1075.2	1369	50653	6.083	3.332
38	119.4	1134.1	1444	54872	6.164	3.362
39	122.5	1194.6	1521	59319	6.245	3.391
40	125.7	1256.6	1600	64000	6.325	3.420
41	128.8	1320.3	1681	68921	6.403	3.448
42	131.9	1385.4	1764	74088	9.481	3.476
43	135.1	1452.2	1849	79507	6.557	3.503
44	138.2	1520.5	1936	85184	6.633	3.530
45	141.4	1590.4	2025	91125	6.708	3.557
46	144.5	1661.9	2116	97336	6.782	3.583
47	147.7	1734.9	2209	103823	6.856	3.609
48	150.8	1800.6	2304	110592	6.928	3.634
49	153.9	1885.7	2401	117649	7.	3.659
50	157.1	1963.5	2500	125000	7.071	3.684
51	160.2	2042.8	2601	132651	7.141	3.708
52	163.4	2123.7	2704	140608	7.211	3.733
53	166.5	2206.2	2899	148877	7.280	3.756
54	169.6	2290.2	2916	157464	7.348	3.780
55	172 8	2375.8	3025	166375	7.416	3.803
56	175.9	2463.0	3136	175616	7.483	3.826
57	179.1	2551.8	3249	185193	7.550	3.849
58	182.2	2642.1	3364	195112	7.616	3.871
59	185.4	2734.0	3481	205379	7.681	3.893
60	188.5	2827.4	3600	216000	7.746	3.915
61	191.6	2922.5	3721	226981	7.810	3.937
62	194.8	3019.1	3844	238328	8.874	3.958
63	197.9	3117.3	3960	250047	7.937	3.979
64	201.1	3217.0	4096	262144	8.	4.
65	204.2	3318.3	4225	274625	8.062	4.021
66	207.3	3421.2	4356	287496	8.124	4.041
67	210.5	3525.7	4489	300763	8.185	4.061
68	213.6	3631.7	4624	314432	8.246	4.082
69	216.8	3739.3	4761	328509	8.307	4.102
70	219.9	3848.5	4900	343000	8.367	4.121
71	223.1	3959.2	5041	357911	8.426	4.141
72	226.2	4071.5	5184	373248	8.485	4.160
73	229.3	4185.4	5329	389017	8.544	4.179
74	232.5	4300.8	5476	405224	8.602	4.198
75	235.6	4417.9	5625	421875	8.660	4.217
76	238 8	4536.5	5776	438976	8.718	4.236
77	241.9	4656.6	5929	456533	8.775	4.254
78	245.0	4778.4	6084	474552	8.832	4.273
79	248.2	4901.7	6241	493039	8.888	4.291
80	251.3	5026.6	6400	512000	8.944	4.309
81	254.5	5153.0	6561	531441	9.	4.327
82	257.6	5281.0	6724	551368	9.056	4.345
83	260.8	5410.6	6889	571787	9.110	4.362
84	263.9	5541.8	7056	592704	9.165	4.379
85	267.0	5674.5	7225	614125	9.220	4.397

REGULAR POLYGONS.

[illegible] number of [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

MENSURATION.

[illegible] of parallel sides.

[illegible] triangles and find area of the [illegible]

[illegible] radius.

[illegible] radius.—area of tri-[illegible] triangle, when the segment [illegible]

[illegible] difference of diam-[illegible]

[illegible] = diameter × .8862, or cir-[illegible]

[illegible] given square = side of [illegible]

[illegible] × .7854.

[illegible] perpendicular from its [illegible]

[illegible] length × circumfer-[illegible]

[illegible] segment × circumfer-[illegible]

[illegible] times the square of [illegible]

[illegible] base × ⅓ of the slant [illegible]

Contents of pyramid or cone=area of base×⅓ altitude.

Surface of frustum of cone or pyramid=sum of circumference at both ends×½ slant height+area of both ends.

Contents of frustum of cone or pyramid=multiply areas of two ends together and extract square root. Add to this root the two areas and ×⅓ altitude.

Contents of a wedge=area of base×½ altitude.

STRENGTH AND TENSION OF IRON.

The breaking strength of good American iron is usually taken at 50,000 lbs. per square inch, with an elongation of 15 per cent. before breaking. It should not set under a strain of less than 25,000 lbs. The proof strain is 20,000 lbs. per square inch and beyond this amount iron should never be strained in practice.

MISCELLANEOUS WEIGHTS.

Barrel flour weighs	196 lbs.
" salt "	280 "
" beef "	200 "
" pork "	200 "
" fish "	200 "
Keg powder	= 25 "
Stone of lead or iron	= 14 "
Pig " "	=21½ stone.

Anthracite coal, broken, cubic foot averages 54 lbs.
A ton, loose, occupies 40 to 43 cubic feet.
Bituminous coal, broken, cubic ft. averages 49 lbs.
A ton, loose, occupies, 43 to 48 cubic feet.

Cement, (Hy.) Rosendale, bushel	=70 lbs.
" " Louisville, "	=62 "
" " Portland, "	=96 "
Gypsum, ground	=70 "
Lime, loose	=70 "
" well shaken	=80 "
Sand at 98 lbs. per cubic feet	=122½ "
18.29 bushels=ton. 1.181 ton	=cu. yd.

A cable's length	=240 yards.
20 articles	=1 score.
12 dozen	=1 gross.
12 gross	=1 great gross.
A cord of wood	=128 cubic ft.
1 hand	=4 inches.
1 span	=9 inches.

SHOEMAKER'S MEASURE.

No. 1 of small size is 4⅛ inches long.
No. 1 of large size is 8 11-24 inches long.
Each succeeding number of either size is one-third of an inch additional length.
60 *pairs of shoes*=1 case.

TREATMENT OF ACCIDENTS, ETC.

To Restore Persons Affected by Cold.

For frost-bite or numbness.—Restore warmth *gradually*, in proportion as circulation in the body or parts increases.

For a frozen limb.—Rub with snow and place in cold water for a short time. When the sensation returns, place again in cold water: add heat *very gradually*, by adding warm water.

If apparently dead or insensible.—Strip entirely of clothes, and cover body, with exception of mouth and nostrils, with *snow* or *ice-cold water*. When the body is thawed, dry it, place it in a *cold* bed; rub with warm hands under the cover; continue this for hours. If life appears, give small injections of camphor and water; put a drop of spirits of camphor on tongue, then rub the body with spirits and water—finally with spirits; then give tea, coffee, or brandy and water.

Send for a physician in all cases.

For Burns or Scalds.

In the early stage, soon after the accident, if there is no separation of the skin, *allow the bladder of water*, of whatever size, to *remain untouched;* merely dress it with a piece of linen or muslin, lightly coated with Simple Cerate.

If the skin comes off, dress the part with cotton, the object is to exclude the air and prevent suppuration. If cotton cannot be procured, apply any covering until you can have an ointment made of beeswax and sweet oil, equal parts—or lime water and linseed oil; or lay on scraped potatoes or carrots, or sprinkle flour on the injured surface when the above cannot be procured. Flour is troublesome to remove.

If the scald is extensive and on the body, *cold applications are not proper*; then use warm fomentations, or, in the case of a child, the warm bath. Keep the air from the wound as much as possible; do not remove the dressing often. When a cold lotion is used, pour it upon the rags, letting them remain undisturbed.

In Cases of Poisoning.

Send for a physician immediately.

In all cases of poisoning, the first step is to evacuate the stomach. This should be effected by an emetic which is quickly obtained, and most powerful and speedy in its operation; such is, powdered mustard (a large teaspoonful in a tumblerful of water), or salt, or ½ teaspoonful powdered ipecac every 10 to 15 minutes. When vomiting has already taken place, copious draughts of warm water or warm mucilaginous drinks should be given to keep up the effect till the poisonous substance has been thoroughly evacuated.

If vomiting cannot be produced the stomach pump must be used.

Poisons. ANTIDOTES.

Acids. The alkalies: common soap in solution is a good remedy. For *nitric* and *oxalic* acids, chalk and water are the best.

Alkalies. The vegetable acids: common vinegar is most used. Oil, as castor or olive, should be given in *large quantities*.

Iodine. Iodide of Potassium. Starch, wheat flour, in large quantities, well mixed with water. Drink freely; afterward strong mixture of vinegar and water.

Arsenic. Any oil or fat. Magnesia in large quantities.

Bismuth, Verdigris, Corrosive Sublimate. White of eggs; milk freely used, or wheat flour mixed with water; followed by an emetic.

Phosphorus. Magnesia with water and copious draughts of mucilaginous drinks.

Opium, Laudanum. Use most active emetics, mustard, etc. Keep patient in motion. Dash cold water on head and shoulders.

Apparent Death from Breathing Noxious Vapors, as in Wells, etc.

Send for a Physician.

If insensible, expose person to open air; sprinkle cold water on face and head; rub strong vinegar about nostrils; give drink of vinegar and water.

If suffocated by breathing fumes of charcoal, proceed as above, and excite breathing as in rules given in case of drowning.

To purify wells, etc., shower water down them until a candle will burn at the bottom with a clear flame.

Sun-Stroke.

Take patient immediately into the shade; place in a half-recumbent position—head raised; loosen cloths about neck and chest; apply immediately ice, or cold wet cloths to the head and nape of the neck, changing them frequently.

Sprains.

Elevate the limb; keep the joint perfectly quiet; apply lukewarm lotions or fomentations. When inflammation has ceased, apply stimulating liniments and bandages; shower the parts with cold and warm water alternately.

Marshall Hall's Rules for the Resuscitation of Persons Apparently Drowned.

1. Treat the patient instantly, on the spot, in the open air, freely exposing the face, neck and chest to the breeze, except in very severe weather.

2. Send with all speed for medical aid and for articles of clothing, blankets, etc.

I. To clear the Throat.—3. Place the patient gently on the face, with one wrist under the forehead. All fluids and the tongue itself then fall forward, and leave the entrance into the windpipe free.

II. To excite Respiration.—4. Turn the patient slightly on his side; apply snuff or other irritant to the nostrils, and dash cold water on the face, previously rubbed briskly until it is warm. If there be no success lose no time, but apply the third rule.

III. To imitate Respiration.—5. Replace the patient on his face. 6. Turn the body gently but completely on the side, and a little beyond, and then on the face, alternately, repeating the measures deliberately, efficiently and preservingly, 15 times in the minute only. This number of thoracic movements per minute acts with the natural order of respiratory thoracic dilations and contractions, corresponding with a slow movement of the heart, averaging something less than 60 pulsations per minute, and therefore merits due attention. The rationale of the operations is thus: When the patient reposes on the thorax, this cavity is compressed by the weight of the body, and expiration is promoted; when he is turned on the side this pressure is removed, and inspiration is facilitated. 7. When the prone

position is resumed make equable but efficient pressure along the spine, removing it immediately before the rotation on the side. (The first measure augments expiration, the second commences inspiration.)

IV. To induce Circulation and Warmth.—8. Continuing these measures, rub the limbs upwards with a firm pressure and with energy, using handkerchiefs, etc. 9. Replace the patient's wet clothing by such other covering as can be instantly procured, each bystander supplying a coat or waistcoat. Meanwhile, and from time to time, proceed to the fifth rule.

V. To excite Inspiration.—10. Let the surface of the body be slapped briskly with the hand; or, 11. Let cold water be dashed briskly on the surface, previously rubbed dry and warm.

GEOMETRY.—Definitions.

A *Point* has position, but not magnitude.

A *Line* is length without breadth, and is either *Right, Curved or Mixed*. When no particular line is specified, a right line is meant.

A *Right Line* is a straight line, or the shortest distance between two points.

A *Mixed Line* is a right line and curved line united.

Lines are *parellel*, *oblique*, *perpendicular*, or *tangentical*, one to another.

An *Area*, *surface*, *superfices*, is the space contained within the outline or perimeter of a figure; it has no thickness, and is estimated in the *square* of some unit of measure, as square *inch*, square *yard*, etc.

A *Solid* has length, breadth and thickness, and its contents are estimated in the *cube* of some unit of measure.

An *Angle* is the diverging of two lines from each other, and is *right*, *acute*, or *obtuse*.

A *Right Angle* has one line perpendicular to another and resting upon it.

A *Triangle*, or *trigon*, is a figure having three sides.

An *Equilateral Triangle* has all its sides equal.

An *Isosceles Triangle* has two of its sides equal.

A *Scalene Triangle* has no two sides equal.

A *Right-angled Triangle* has one right angle.

An *Obtuse-angled Triangle* has one obtuse angle.

An *Acute-angled Triangle* has all its angles acute.

A *Quadrangle*, *tetragon*, *quadrilateral*, is a figure having four sides.

A *Parallelogram* is a quadrilateral figure whose opposite sides are parallel and equal.

A *Rectangle* is a parallelogram whose opposite sides are equal, its angles right angles, and its length greater than its breadth.

A *Square* is an equilateral rectangle, having all its sides equal.

A *Rhomboid* is a quadrilateral, having its opposite sides equal and parallel, its angles oblique, and a length greater than its breadth.

A *Rhombus*, or *lozenge*, is an equilateral four-sided figure, having oblique angles.

A *Trapezium* is a quadrilateral having no two sides parallel.

A *Trapezoid* is any four-sided figure having two of its sides parallel, but of unequal length.

A *Diagonal* is a line joining any two opposite angles of a figure having four or more sides.

A *Polygon* is a plain figure having more than four sides.

A *Regular Polygon* has all its sides equal.

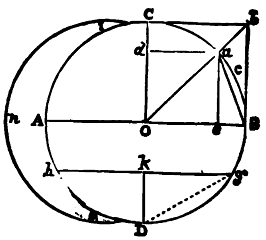
An *Irregular Polygon* has not all its sides equal.

A *Pentagon* has five sides; a *hexagon*, six; a *heptagon*, seven; an *octagon*, eight; a *nonagon*, nine; a *decagon*, ten; an *undecagon*, eleven; a *dodecagon*, twelve.

A *Perimeter* of a figure is its bounds, limits, or outline. It is to other figures what the *circumference* is to the circle, and the perimeter of any portion of a figure is the outline of that portion.

The *Altitude*, or height, of a figure, is a perpendicular let fall from its *vertex*, or highest point, to the opposite side or end, its *base*.

The *Base* of a triangle is that side that is placed parallel to the horizon; and of figures in general the base is that end, or side, upon which the figure is supposed to stand or rest. The sides of a triangle are often called the *legs*. In a right-angled triangle, the longest side, or line which subtends the right angle, is called the *hypothenuse*, and of the other two sides, one is the base, and the other the perpendicular.



A circle is a plane figure, bounded by a curve line, called the *circumference*, or *periphery*, every part of which is equi-distant from a point within called the *centre*, as A B C D, in the diagram. The circumference itself is often called a circle.

The *Radius—semi-diameter—*is a line drawn from the centre to the circumference, as O A, or O C.

The *Diameter* is a line drawn from the circumference through the centre to the opposite side, as A B.

A *Semicircle* is half a circle, or it is half the circumference of a circle, as A C B.

A *Quadrant* is a quarter of a circle. It is also sometimes a quarter of the circumference, as A C.

An *Arc* is any portion of the circumference, as B *c a*, or *h* D *g*.

A *Chord*, or *subtense*, is a right line joining the extremities of an arc, as B *a*, or *h g*.

A *Segment* is the portion of a circle contained between the arc and its chord, as the space between the arc *h* D *g* and its cord *h g*,—it is the top part of a figure, cut by a plane parallel to its base.

A *Sector* is the space between two radii, or lines passing from the centre to the circumference, as the space B O *a*.

A *Secant* is a line that cuts another line. In trigonometry, the secant of an arc is a right line drawn from the centre of a circle through one end of the arc, and terminated by a tangent drawn through the other end: thus the secant of the arc B *c a* is the line O *b*.

A *Cosecant* is the secant of the complement of an arc, as O *b*.

A *Sine* of an arc is a line drawn from one end of the arc perpendicular to a radius drawn through the other end, as *a e*, and is always equal to half the chord of double the arc; and the sine of an angle is the sine of the arc that measures that angle.

The *Versed Sine* is that portion or part of the radius lying between the sine and the end of the arc or angle, as *e* B, and the *versed sine of half the arc* is that portion of the radius lying between the chord and the arc, bisecting or dividing both at their centres, as *k* D, in the arc *h* D *g*. It is the height of the arc, or segment.

The *Cosine* of an arc, or angle, is that portion of the radius lying between the sine and the centre, as *e* O.

The *Coversed Sine* is the sine of the complement of an arc, or angle, or the coversed sine of the given arc, or angle; thus, the line *a d* is the *coversed sine of the arc B c a*, or of the angle B O.

A *Tangent* is a right line that touches a curve, and which, if produced, will not cut it—the tangent of the arc B *c a*, is B *b*.

A *Cotangent* is the tangent of the complement of an arc, or the tangent of an arc which is the complement of another arc to ninety degrees; thus, the cotangent to the arc B *c a*, is the line C *b*.

The *Complement* is what remains of the quadrant of a circle, after the angle has been taken therefrom—the complement of the arc B *c a*, is *a* O C.

The *Supplement* is what remains of a semi-circle after taking an angle therefrom—the supplement of the arc B *c a*, is *a* O A.

A *Gnomon* is the space included between two similar parallelograms, one inscribed within the other, and having one angle common to them both, as the space C *b* B *e a d* C.

A *Zone* is the space between two parallel chords of a circle—the space included between the lines A B and *h g*.

A *Lune*, or *Crescent*, is the space contained between the intersecting arcs of two *eccentric* circles, as *i n s*.

A *Circular Ring* is the space between the circumferences of two *concentric* circles.

A *Prism* is a solid whose bases or ends are any similar, equal plane figures, and whose sides are parallelograms.

A *Parallelopiped* is a solid having six sides, its angles right angles, and its opposite sides equal. It is a prism, therefore, whose base is a parallelogram.

A *Cube* is a solid having six equal sides and all its angles right angles. It is a square prism.

A *Prismoid* is a solid whose bases are parallel but unequal, and whose sides are quadrilateral.

A *Pyramid* is a solid having any plane rectilinear figure for its base, and all its sides, more or less, terminating in a point, called its *vertex*, or *summit*.

A *Cylinder* is a circular solid, having a uniform diameter, and equal and parallel circles for its end.

A *Cone* is a solid, having a circle for its base, and a true taper therefrom to its vertex.

Conic Sections are the figures made by a plane cutting a cone; they are the *ellipse*, *parabola*, and *hyperbola*.

An *Ellipse*, or *oval*, is a figure generated from the section of a cone, by a plane cutting both sides of it obliquely to the base.

A *Parabola* is the section of a cone cut by a plane parallel to one of its sides.

A *Hyperbola* is the section of a cone cut by a plane making a greater angle with the base than the side of the cone makes.

A *Conoid* is a solid generated by the revolving of a parabola or hyperbola around its axis.

A *Spheroid* is a solid generated by the revolving of an ellipse about either of its axis or diameter.

The *Transverse*, or *major*, axis of an ellipse is its longest diameter, or the distance, lengthwise, through the centre.

The *Conjugate*, or *minor*, axis of an ellipse is the shorter of the two diameters—a right line bisecting the transverse. If the generating ellipse revolves about its major axis, the spheroid is *prolate*, or *oblong*; if about its minor axis, it is *oblate*, or flattened.

An *Ordinate* is a right line drawn from any point of the curve of a conic section to either of its diameters, and perpendicular to that diameter. *Either semi-diameter* of an ellipse, or other conic section, may be an ordinate. *It is the sine* of the arc, in the equation of the circle.

The *Abscissæ* of a conic section are the parts of either diameter or axis, lying between the respective vertices and an ordinate.

The *Parameter—latus rectum* of a parabola—is a third proportional to any diameter and its conjugate. In the parabola it is a third proportional to any abscissa and its ordinate, extended through the diameter to the opposite side.

The *Focus* is the point in the axis where the ordinate is equal to half the parameter.

A *Sphere*, or *globe*, is a perfectly round substance—a solid contained under a curved surface, every point of which is equally distant from a point within, called the centre. Its axis, or diameter, is any right line passing from a side through the centre to the opposite side. A hemisphere is half a sphere.

A *Frustum* of any solid figure, as of a cone, pyramid, etc., is the part remaining after a segment has been cut off.

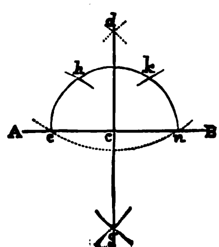
An *Ungula* is the section of a cylinder cut off by a plane oblique to the base.

The *Slant Height* of a regular figure is the length of one of its sides, or the distance from the outline of its base to its vertex, or summit.

To Bisect or Divide a Line, A B, into Two Equal Parts.

Set one foot of the dividers in A, and with the other extended so as to reach somewhat beyond the middle of the line, describe arcs above and below the line; then, with the foot of the dividers in B, describe arcs crossing the former; a line drawn from the intersection of the arcs above the line to the intersection of those below, will divide the line into two equal parts.

To erect a perpendicular on a given point in a straight line, or to draw a line at a right angle to another line.



Set one foot of the dividers in the given point *c*, and with the other extended to any convenient distance, as to A, mark equal distances on each side *c*, as *c* A, *c* B; and from A and B as centres, with the dividers extended to a distance somewhat greater than that between *c* and A, or *c* and B, describe arcs cutting each other above the line, as at *d*; a line drawn from the intersection of the arcs *d*, to the point *c*, will be perpendicular to the line A B, or will form a right angle with the line *c* A, or *c* B.

From a Point, *d*, to Let Fall a Line Perpendicular to Another Line, A B.

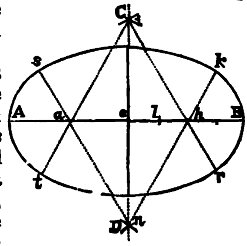
Set one foot of the dividers in *d*, and with the other extended so as to reach beyond the line A B, describe an arc cutting the line A B, in *e* and *n*; then with one foot of the dividers in *e*, and the other extended to more than half the distance between *e* and *n*, describe the arc *g*; then with one foot of the dividers in *n*, describe an arc cutting the arc *g* in *g*; a line drawn from the point *d* through *c* to the intersection of the arcs at *g*, will be the perpendicular required.

To Erect a Perpendicular upon the End of a Line, as at *c*, on the Line A *c*.

Set one foot of the dividers in *c*, and, at any convenient radius, describe the arc *e h k*; with one foot of the dividers in *e*, cut the arc in *h*, and with

one foot in *h*, cut it in *k*; from *h* as a centre, and *k* as a centre, describe arcs cutting each other at *d*; a line drawn from the intersection of the arcs, *d*, to the point *c*, will be perpendicular to the line A *c*.

To Describe an Ellipse of Given Length and Breadth.



Let the line A B equal the given length, or transverse diameter, and the line C D the conjugate, and let these lines bisect each other, forming right angles, on either side, as at *e*. Lay off the distance C D on the line A B, as from A to *l*, and divide the distance *l* B into three equal parts. From *e*, on the line A B, set off two of the parts each way, as *e a*, *e h*; and from *a*, or *h*, designate the distance *a h* on the line C D, as at *i* and *n*; from *i* draw the lines *i t* and *i r*, and from *n*, the lines *n s* and *n k*, passing through the points *a* and *h*, and cutting each other therein. From the point *n*, as a centre describe the arc *s k*, and from *i*, as a centre, the arc *r t*; also, from *a*, as a centre, describe the arc *t s*, and from *h*, as a centre, the arc *k r*, and the required ellipse is drawn.

Note.—An architrave of any depth desired may be readily described on the above.

WEIGHT OF METALS IN PLATE.

Sheet Copper. Thickness, etc.

Unit of size 4 feet by 2 feet.

70 lb. plate - -	=3-16 in.	11½ lb. plate - -	=1-32 in.
46½ " " - -	=⅛ "	6 " " - -	=1-64 "
23 " " - -	=1-16 "		

Sheet Lead.

Unit of size 1 square foot.

15 lb. sheet -	=¼ in. thick.	6 lb. sheet - -	=1-10 in. th.
11 " -	=3-16 " "	4 " - -	=1-16 "
7½ " -	=⅛ " "		

The weight of a square foot one inch thick of

Malleable Iron, - - - -	=40.554 lbs.
Penn. plate, - - - - -	=40.464 "
Cast iron, - - - - -	=37.584 "
Copper, wrought - - - -	=46.240 "
" cast - - - - -	=45.771 "
Brass, plate - - - - -	=44.812 "
Zinc, cast, pure, - - - -	=35.734 "
" sheet - - - - -	=37.448 "
Lead, cast - - - - -	=59.125 "
Steel, - - - - -	=40 829 "

And for any other thickness, greater or less, it is the same in proportion; thus, a square foot of sheet copper 1-16 of an inch thick=46.24÷16=2.89 And 5 square feet at that thickness=2.89×5=14.45 lbs., etc. So, too, ıre feet at 2½ inches thickness=46.24×2.5×5=578 lbs.

THERMOMETERS.

	Boiling Point.	Freezing Point.
Fahrenheit=	212°	32°
Centigrades=	100°	0°
Reaumur=	80°	0°

Let F=No. of degrees Fahrenheit.
" C= " " " Centigrade.
" R= " " " Reaumur.

Then, to convert

Fah. to Cent.

$$\frac{5(F-32)}{9}=C$$

Cent. to Fah.

$$\frac{9\,C}{5}+32=F.$$

Fah. to Reaum.

$$\frac{4(F-32)}{9}=R$$

Reaum. to Fah.

$$\frac{9\,R}{4}+32=F.$$

Quantity of Water that will Flow through a Pipe 500 Feet Long in 24 Hours, with a Fall of 10 Feet.

$\frac{3}{8}$ inch bore,	576 gallons.		$\frac{3}{4}$ inch bore,	3,200 gallons.
$\frac{1}{2}$ " "	1,150 "		1 " "	6,624 "
$\frac{5}{8}$ " "	2,040 "		$1\frac{1}{4}$ " "	10,000 "

Joints to lead pipes require 1 lb. of solder for every inch diameter.

INTEREST RULES.

In addition to the rules and tables, several short methods are given:—

Take half the amount in dollars, as cents it will be the interest per month at 6%.

For finding the interest on any principal for any number of days. The answer in each case being in cents, separate the two right hand figures of the answer to express it dollars and cents:

Four per cent. Multiply by the number of days and divide by 90.
Five per cent. Multiply by the number of days and divide by 72.
Six per cent. Multiply by the number of days, separate the right-hand figure, and divide by 6.
Seven per cent. Multiply by the number of days and divide by 52.
Eight per cent. Multiply by the number of days and divide by 45.
Nine per cent. Multiply by the number of days; separate the right-hand figure and divide by 4.
Ten per cent. Multiply by the number of days and divide by 36.
Fifteen per cent. Multiply by the number of days, and divide by 24.
Eighteen per cent. Multiply by the number of days; separate the right-hand figure, and divide by 2.
Twenty per cent. Multiply by the number of days, and divide by 18.

Compound Interest.

The rule for calculating compound interest is to add the interest to the principal, and calculate the interest on the sum. The use of the following table will shorten this tedious process. It gives the amount for one dollar at 5, 6 and 7 per cent., for from 1 to 20 years.

Multiply the amount for $1 by the given number of dollars, and the product is the answer.

TABLE

Showing the Amount of $1 at Compound Interest for any Number of Years, not Exceeding Twenty.

Years.	5 per cent.	6 per cent.	7 per cent.
1	1.050000	1.060000	1.070000
2	1.102500	1.123600	1.144900
3	1.157625	1.191016	1.225043
4	1.215506	1.262477	1.310796
5	1.276282	1.338226	1.402552
6	1.340096	1.418519	1.500730
7	1.407100	1.503630	1.605781
8	1.477455	1.593848	1.718186
9	1.551328	1.689479	1.838459
10	1.628895	1.790848	1.967151
11	1.710339	1.898299	2.104852
12	1.795856	2.012196	2.252192
13	1.885649	2.132928	2.409845
14	1.979932	2.260904	2.578534
15	2.078928	2.396558	2.759032
16	2.182875	2.540352	2.952164
17	2.292018	2.692773	3.158815
18	2.406619	2.854339	3.379932
19	2.526950	3.025600	3.616526
20	2.653298	3.207135	3.869684

Note.—The above table is available for British money by reading pounds and decimals of a pound, for dollars and decimals of dollars.

To find the time in which any sum will double itself at compound interest, at any rate not exceeding 10% per annum.

Rule.—Divide 70 by the rate of interest, and take the whole number nearest the quotient. This is the number of years.

Rate.		Years.
3	70÷3=	23
4	70÷4=	17
5	70÷5=	14
6	70÷6=	12
7	70÷7=	10
8	70÷8=	9
9	70÷9=	8
10	70÷10=	7

STRENGTH OF ICE.

A thickness of 2 inches will allow the passage of men in single file on a line of planks placed on the ice. No other row of planks should be placed nearer than 6 feet.

A thickness of 5 inches will allow the passage of cavalry, carts or light guns, with moderate interval between each.

A thickness of 6 inches will allow the passage of wagons drawn by horses, etc.

A thickness of 10 to 12 inches will support the heaviest load ever likely to pass over it.

SPECIFIC GRAVITIES.

The specific gravity of a body is its weight relative to the weight of an equal bulk of pure water at the maximum density (39°.83, b. 30 in.), the water being taken as 1., a cubic foot of which weighs 1000 avoirdupois ounces, or 62½ lbs. The specific gravity, therefore, of any body multiplied by 1000, or, which is the same thing, the decimal being carried to three places of figures, or thousands, as in the following tables, the whole taken as an integer equals the number of ounces in the cubic foot of the material; multiplied by 62.5, or considered an integer and divided by 16, it equals the number of pounds in a cubic foot; and multiplied by .036169, or taken as an integer and divided by 27648, it equals the decimal fraction of a pound per cubic inch; by which it is readily seen, the specific gravity of a commodity being known, its weight per any given bulk is easily and accurately ascertained; as also, its specific gravity, the weight and bulk being known. The weight of any one article relative to that of any other, is as its respective specific gravity to the specific gravity of the other.

METALS.	Spe. Grav.	METALS.	Spe. Grav.
Antimony	6.712	Platinum, hammered	20.337
Arsenic	8.310	" rolled	22.069
Bismuth	9.823	Potassium, 60°	0.865
Bronze	8.700	Palladium	11.870
Brass, com.	8.604	Rhodium	11.000
Copper, cast	8.788	Silver, pure, cast	10.474
" wire-drawn	8.878	" hammered	10.511
Cadmium	8.604	Sodium	0.970
Cobalt	7.700	Steel, soft	7.836
Chromium	5.900	" tempered	7.818
Glucinium	3.000	Tin, cast	7.291
Gold, pure, cast	19.258	Tellurium	6.115
" pure, hammered	19.546	Tungsten	17.600
Iridium	15.363	Titanium	4.200
Iron, cast	7.209	Uranium	9.000
" wrought	7.787	Zinc, cast	6.861
Lead	11.352		
Mercury, 32°	13.598	STONES AND EARTH.	
" 60°	13.580	Alabaster, white	2.730
" —39°	15.000	" yellow	2.699
Manganese	8.013	Amber	1.078
Molybdenum	8.611	Asbestos, starry	3.073
Nickel	8.280	Borax	1.714
Osmium	10.000	Bone, ox	1.656
Platinum, cast	19.500	Brick	1.900

	Spe. Grav.
Chalk, white	2.782
Charcoal	.441
" triturated	1.380
Cinnabar	7.786
Clay	1.934
Coal, bitum. avg	1.270
" anth. "	1.520
Coral, red	2.700
Earth, loose	1.500
Emery	4 000
Feldspar	2.500
Flint, white	2.594
" black	2.582
Garnet	4.085
Glass, flint	2.933
" white	2.892
" plate	2.710
" green	2.642
Granite, red	2.625
" Lockport	2.655
" Quincy	2.652
" Susquehanna	2.704
Grindstone	2.143
Gypsum, opaque	2.168
Hone, white	2.876
Hornblende	3.600
Ivory	1.822
Jasper	2.690
Limestone, green	3.180
" white	3.156
Lime, compact	2.720
" foliated	2.837
" quick	0.804
Loadstone	4.930
Magnesia, hyd	2.333
Marble, common	2.686
" white Ital	2.708
" Rutland, Vt	2.708
" Parian	2.838
Nitre, crude	1.900
Pearl, oriental	2.656
Peat, hard	1.329
Porcelain, China	2.385
Porphyra, red	2.766
" green	2.675
Quartz	2.647
Rock Crystal	2.654
Ruby	4.283
Stone, common	2.520
" paving	2.416
" pumice	0.915
" rotten	1.981
Salt, common, solid	2.130
Saltpeter, refined	2.090
Sand, dry	1.800
Serpentine	2.430

	Spe. Grav
Shale	2.600
Slate	2.672
Spar, fluor	3.156
Stalactite	2.324
Talc, black	2.900
Topaz	4.011

SIMPLE SUBSTANCES,

Neither Metallic nor Gaseous.

Boron	1.968
Bromine	2.970
Carbon	3.521
Iodine	4.943
Phosphorus	1.770
Selenium	4.320
Silicon	1.184
Sulphur	1.990

WOODS.—*Dry.*

Apple	0.793
Alder	.800
Ash	.845
Beech	.850
Birch	.720
Box, French	1.328
Box, Dutch	.912
Cedar	.561
Cherry	.715
Chestnut	.610
Cocoa	1.040
Cork	.240
Cypress	.644
Ebony, American	1.331
" foreign	1.290
Elm	.671
Fir, yellow	.657
" white	.569
Hacmetac	.592
Hickory, red	.900
Lignum vitæ	1.333
Larch	.544
Logwood	.913
Mahogany, Spanish, best	1.065
" " com	.800
" St. Domingo	.720
Maple, red	.750
Mulberry	.897
Oak, live	1.120
" white	.785
Orange	.705
Pear	.661
Pine, white	.554
" yellow	.568
Poplar, white	.383
Plum	.785
Quince	.705

	Spe. Grav.
Spruce, white	.551
Sassafras	.482
Sycamore	.604
Walnut	.671
Willow	.585
Yew, Spanish	.807
" Dutch	.788

Highly Seasoned American.

Ash, white	.722
Beech	.624
Birch	.526
Cedar	.452
Cherry	.606
Cypress	.441
Elm	.600
Fir	.491
Hickory, red	.838
Maple, hard	.560
Oak, white, upland	.687
" James River	.759
Pine, yellow	.541
" pitch	.536
" white	.473
Poplar, (tulip)	.587
Spruce, white	.495

GUMS, FATS, ETC.

Asphaltum	.905 / 1.650
Beeswax	.965
Butter	.942
Camphor	.988
Gamboge	1.222
Gunpowder	.900
" shaken	1.000
" solid	1.550 / 1.800
Gum, Arabic	1.454
" Caoutchouc	.933
" Mastic	1.074
Honey	1.450
Ice	.930
Indigo	1.009
Lard	.941
Pitch	1.150
Rosin	1.100
Spermaceti	.943
Starch	1.530
Sugar, dry	1.606
Tallow	.938
Tar	1.015

LIQUIDS.

	Spe. Grav.
Acid, acetic	1.062
" citric	1.034
Acid, fluoric	1.060
" nitric	1.485
" nitrous	1.420
" sulphuric	1.846
" muriatic	1.200
" silicic	2.660
Alcohol, anhy	.794
" 90%	.834
Beer	1.034
Blood, human	1.054
Camphene, pure	.863
Cider, whole	1.018
Ether, sulph	.715
" nitric	.908
Milk, cow's	1.032
Molasses, 75%	1.400
Oils, linseed	.934
" olive	.917
" rapeseed	.927
" sassafras	1.090
" turpentine, com	.875
" sperm, pure	.874
" whale, purified	.923
Proof spirits	.925
Vinegar	1.025
Water, pure	1.000
" sea	1.026
" Dead sea	1.240
Wine, champagne	.997
" claret	.994
" port	.997
" sherry	.992

ELASTIC FLUIDS.

The measure of which is atmospheric air, at 60°, b. 30 in., its assumed gravity 1; one cubic foot of which weighs 527.04 grains.=.305 of a grain per cubic inch. It is at this temperature and density, to pure water at the maximum density, as .0012046 to 1, or as 1 to 830.1.

SIMPLE OR ELEMENTARY GASES.

Hydrogen	.0689
Oxygen	1.1025
Nitrogen	.9760
Fluorine	
Chlorine	2.470
Carbon, vapor of, (theoretically)	4.24

COMPOUND GASES.

Ammoniacal	.591
Carbonic acid	1.525
" oxide	.763
Carbureted hydrogen	.559

	Spe. Grav.		Spe. Grav.
Chloro-carbonic	3.389	Sulphureted	1.177
Cyanogen	1.818	Steam, 212°	.490
Muriatic acid gas	1.247	Smoke, of wood	.900
Nitrous " "	3.176	" of coal	.102
" oxide "	1.040	Vapor, of water	.623
Olefiant	.982	" of alcohol	1.613
Phosphureted hydrogen	1.185	" of spirits turpentine	5.013

WEIGHT PER BUSHEL (EVEN WINCHESTER) OF DIFFERENT GRAINS, SEEDS, ETC., ETC.

Articles.	Lbs.	Articles.	Lbs.
Barley	47	Hemp seed	48
Beans	63	Oats	32
Buckwheat	46	Peas	64
Blue-grass seed	14	Rye	56
Corn	56	Salt, T. I.,	80
Cranberries		" boiled	56
Clover seed	60	Timothy seed	56
Dried apples	22	Wheat	60
" peaches	33	Potatoes, h'p'd	60
Flax seed	52		

NUMBER OF NAILS (BY COUNT), IRON MACHINE CUT, OF DIFFERENT DESCRIPTIONS, IN A POUND.

Description.	No.	Description.	No.
3 penny	600	10 penny	88
4 "	360	12 "	68
6 "	200	20 "	40
8 "	110		

METRIC SYSTEM.

By an Act of Congress, approved in July, 1867, the use of the Weights and Measures of the Metric System is permissible; and contracts are declared not to be invalid because of the weights and measures expressed or referred to therein are of that system.

The metre was designed to be the ten-millionth ($\frac{1}{10,000,000}$) part of the earth's meridian passing through Dunkirk and Formentera. Later investigations, however, based on additional measures of meridional arcs in other parts of the world have shown that the metre sensibly exceeds such ten-millionth part. Sir John Herschel states this excess to be one part in 6400.

The METRE is the unit or base of the measure of length, the ARE of that of surface, the STERE of cubic, the GRAMME of that of weight, and the LITRE of that of capacity.

The Metre................ =39.371 U. S. inches.
" Are.............. ....
100 sq. Metres........ } =3.95387 " square rods.

The Stere............ .... } = 35.31714 U. S. cubic feet.
1 cubic Metre .... }
" Litre ... . } = { 61.02803 " " inches.
1 cu. Decimetre..... } = { 2.11352 " wine pints.
" Gramme............ = 15.43315 Troy grains.

The fractional divisions of each of these units are expressed by the same prefixes, viz., *milli*, *centi*, *deci*; and the multiples of each by *deca*, *hecto*, *kilo*, *myria*;—thus *milli*gramme, *centi*gramme, etc., *milli*metre, *centi*metre, etc. To illustrate with the metre—

10 *milli*metres......................= 1 *centi*metre.
10 centimetres......................= 1 *deci*metre.
10 decimetres......................= 1 metre.
10 metres ....= 1 *deca*metre.
10 decametres ....= 1 *hecto*metre.
10 hectometres......................= 1 *kilo*metre.
10 kilometres ....= 1 *myria*metre.

TABLE

EXHIBITING THE WEIGHT IN POUNDS OF ONE FOOT IN LENGTH OF WROUGHT OR ROLLED IRON OF ANY SIZE, (CROSS SECTION,) FROM 1/8 INCH TO 12 INCHES, SQUARE BAR.

Size in Inches.	Weight in Pounds.	Size in Inches.	Weight in Pounds.	Size in Inches.	Weight in Pounds.	Size in Inches.	Weight in Pounds.
1/8	.053	2 3/8	19.066	4 5/8	72.305	7 3/4	203.024
1/4	.211	2 1/2	21.120	4 3/4	76.264	8	216.336
3/8	.475	2 5/8	23.292	4 7/8	80.333	8 1/4	230.068
1/2	.845	2 3/4	25.560	5	84.480	8 1/2	244.220
5/8	1.320	2 7/8	27.939	5 1/8	88.784	8 3/4	258.800
3/4	1.901	3	30.416	5 1/4	93.168	9	273.792
7/8	2.588	3 1/8	33.010	5 3/8	97.657	9 1/4	289.220
1	3.380	3 1/4	35.704	5 1/2	102.240	9 1/2	305.056
1 1/8	4.278	3 3/8	38.503	5 5/8	106.953	9 3/4	321.332
1 1/4	5.280	3 1/2	41.408	5 3/4	111.756	10	337.920
1 3/8	6.390	3 5/8	44.418	5 7/8	116.671	10 1/4	355.136
1 1/2	7.604	3 3/4	47.534	6	121.664	10 1/2	372.672
1 5/8	8.926	3 7/8	50.756	6 1/4	132.040	10 3/4	390.628
1 3/4	10.352	4	54.084	6 1/2	142.816	11	408.960
1 7/8	11.883	4 1/8	57.517	6 3/4	154.012	11 1/4	427.812
2	13.520	4 1/4	61.055	7	165.632	11 1/2	447.024
2 1/8	15.263	4 3/8	64.700	7 1/4	177.672	11 3/4	466.684
2 1/4	17.112	4 1/2	68.448	7 1/2	190.136	12	486.656

To determine the weight, in pounds, of one foot in length, or of any length, of a bar of any of the following metals of form prescribed, of any size, multiply the weight in pounds, of an equal length of square rolled iron of the same size, (see table of square rolled iron,) if the weight be sought of

Iron, Round rolled, by .... .7854
Steel, Square " " 1.0064
" Round " " .... .7904
Cast iron, Square bar " .... .9258

Cast iron,	Round bar,	by	.7271
Copper,	Square rolled,	"	1.1422
"	Round "	"	.8971
Brass,	Square "	"	1.105
"	Round "	"	.8679
Bronze,	Square bar,	"	1.1173
"	Round "	"	.8775
Lead,	Square "	"	1.4579
"	Round "	"	1.145

The weight of a bar of any metal, or other substance, of any given length, of a flat form (and any other form may be included in the rule), is readily obtained by multiplying its cubic contents (feet or inches) by the weight (pounds, ounces or grains) of a cubic foot or inch of the article sought to be weighed; that is—

Length × breadth × thickness × weight per unity of measure.

For the weight in pounds of a cubic foot or inch of different metals, (see table of "Weights of Metals per Measure of Solidity, etc.")

OR, FOR FLAT OR SQUARE BAR.

Multiply the sectional area in inches by the length in feet, and that product, if the metal be

Wrought iron,	by	3.3795
Cast "	"	3.1287
Steel,	"	3.4

EXAMPLE:—Required the weight of a bar of steel, whose length is 7 feet, breadth 2½ inches, and thickness ¾ of an inch.

$2.5 \times .75 \times 7 \times 3.4 = 44.625$ lbs. *Ans.*

EXAMPLE:—Required the weight of a cast iron beam, whose length is 14 feet, breadth 9 inches, and thickness 1½ inch.

$14 \times 9 \times 1.5 \times 3.1287 = 591.32$ lbs. *Ans.*

TABLE.

COMPARATIVE WEIGHT OF METALS, WEIGHT PER MEASURE OF SOLIDITY.

Metals.	Spec. Grav.	Ratio of Comparison	Pounds in a Cubic	
			Foot.	Inch.
Iron, wrought or rolled	7.787	1.	485.68	.28100
Cast iron	7.209	.9258	451.00	.26100
Steel, soft, rolled	7.836	1.0064	489.75	.28342
Copper, pure	8.878	1.1422	554.88	.32111
Brass, common	8.604	1.1050	537.75	.3112
Bronze, gun metal	8.700	1.1173	543.75	.31464
Lead	11.352	1.4579	709.50	.4106

TABLE

EXHIBITING THE WEIGHT OF 100 FEET IN LENGTH OF DIFFERENT NOS. OF DIFFERENT KINDS OF WIRE, WITH SIZE IN DECIMALS OF AN INCH.

No.	Size in Dec'ls	Iron. Lbs.	Brass. Lbs.	Copper. Lbs.
1	.300	25.924	28.646	29.610
2	.284	22.580	24.951	25.791
3	.259	19.469	21.514	22.238
4	.238	16.589	18.331	18.949
5	.220	13.940	15.403	15.922
6	.203	11.520	12.730	13.159
7	.180	9.332	10.311	10.658
11	.120	4.147	4.582	4.737
16	.065	1.087	1.145	1.184
22	.028	.2592	.2864	.2961
30	.012	.0518	.0572	.0592

NOTE.—To convert the decimal of a pound into ounces, multiply it by 16; thus, the weight of 100 feet of No. 22 iron wire, is $.2592 \times 16 = 4.1472$ ounces.

WEIGHT OF PIPES.

The weight of one foot in length of any pipe, of any diameter and thickness, may be ascertained by multiplying the square of its exterior diameter, in inches, by the weight of 12 cylindrical inches of the material of which the pipe is composed, and by multiplying the square of its interior diameter, in inches, by the same factor and subtracting the product of the latter from that of the former, the remainder or difference will be the weight. This is evident from the fact that the process obtains the weight of two solid cylinders of equal length (one foot), the diameter of one being that of the pipe, and the other that of the vacancy, or bore. For very large pipes, the dimensions may be taken in feet, and the weight of a cylindrical foot of the material used as the factor, or multiplier, if desired.

The weight of 12 cylindrical inches (length 1 ft., diameter 1 in.) of

Malleable iron........................	= 2.6543	lbs.
Cast iron.............................	= 2.4573	"
Copper, wrought......................	= 3.0317	"
Lead, "	= 3.8697	"
Cast iron—1 cyl. foot—................	= 353.86	"

Therefore—EXAMPLE.—Required the weight of a copper pipe whose length is 5 feet, exterior diameter $3\frac{1}{4}$ inches, and interior diameter 3 in.

$$3\tfrac{1}{4} = \tfrac{13}{4} \times \tfrac{13}{4} = 10.5625 \times 3.0317 = 32.022+$$
$$3 \times 3 = 9 \times 3.0317 \qquad = 27.285+$$

Ans. $4.737 \times 5 = 23.685$ pounds.

EXAMPLE.—Required the weight of a cast iron pipe, whose length is 10 feet, exterior diameter 38 inches, and interior diameter 3 feet.

$38^2 \times 2.4573 - 36^2 \times 2.4573 = 363.68 \times 10 = 3636.8$ lbs. *Ans.*

Or, $\overline{38^2 - 36^2} = 148 \times 2.4573 = 363.68 \times 10 = 3636.8$ lbs. Ans.

EXAMPLE.—Required the weight of a lead pipe, whose length is 1200 feet, exterior diameter $\frac{7}{8}$ of an inch, and interior diameter 9-16 of an inch.

$\frac{7}{8}\times\frac{7}{8}=\frac{49}{64}=.765625$, and $\frac{9}{16}\times\frac{9}{16}=\frac{81}{256}=316406$, and $.765625-.316406=449219\times3.8697\times1200=2086$ lbs. *Ans.*

EXAMPLE.—The length of a cast iron cylinder is 1 foot, its exterior diameter is 12 inches, and its interior diameter 10 inches; required its weight.

$12^2-10^2=44\times2.4573=108.12$ lbs. *Ans.*
Or, 144 : 353.86 :: 44 : 108.12 lbs. *Ans.*

TABLE

SHOWING THE COEFFICIENTS OF WEIGHT, IN POUNDS, OF ONE FOOT IN LENGTH, OF VARIOUS THICKNESS, OF DIFFERENT KINDS OF PIPE, OF ANY DIAMETER WHATEVER.

Thickness in Inches.	Wrought Iror	Copper.	Lead.
1-32	.332	.379	.484
1-16	.664	.758	.9675
3-32	.995	1.137	1.451
$\frac{1}{8}$	1.327	1.516	1.935
5-32	1.658	1.894	2.417
3-16	1.99	2.274	2.901
7-32	2.323	2.653	3.386
$\frac{1}{4}$	2.654	3.032	3.87
5-16	3.318	3.79	4.837
$\frac{3}{8}$	3.981	4.548	5.805

CAST IRON.

Thickness.	Factor.	Thickness.	Factor.	Thickness.	Factor.
3-16	1.842	$\frac{5}{8}$	6.143	$1\frac{1}{4}$	12.287
$\frac{1}{4}$	2.457	$\frac{3}{4}$	7.372	$1\frac{1}{2}$	14.744
$\frac{3}{8}$	3.686	$\frac{7}{8}$	8.6	$1\frac{3}{4}$	17.201
$\frac{1}{2}$	4.901	1	9.829	2	19.659

To obtain the weight of pipes by means of the above table—

RULE.—Multiply the diameter of the pipe, taken from the interior surface of the metal on the one side to the exterior surface on the opposite (interior diameter+thickness), in inches, by the number in the table under the respective metal's name, and opposite the thickness corresponding to that of the pipe—the product will be the weight, in pounds, of one foot in length of the pipe, and that product multiplied by the length of the pipe, in feet, will give the weight for any length required.

EXAMPLE.—Required the weight of a copper pipe whose length is 5 feet, interior diameter and thickness $3\frac{1}{8}$ inches, and thickness $\frac{1}{8}$ of an inch.

$3\frac{1}{8}=25\text{-}8=3.125\times1.516\times5=23.687$ lbs. *Ans.*

EXAMPLE.—Required the weight of a cast iron pipe, 10 feet in length, whose interior diameter is 3 feet, and whose thickness is 1 inch.

$36+1=37\times9.829\times10=3636.73$ lbs. *Ans.*

NOTE. For each joint, add 1 foot in length of pipe.

GAUGING.

RULES—For finding the capacity in gallons or bushels of different shaped Cisterns, Bins, Casks, etc., and also, by way of examples, for constructing them to given capacities.

RULE 1. When the vessel is rectangular. Multiply the interior length, breadth, and depth, in feet together, and the product by the capacity of a cubic foot, in gallons or bushels, as desired for its capacity.

RULE 2. When the vessel is cylindrical. Multiply the square of its interior diameter in feet, by its interior depth in feet, and the product by the capacity of a cylindrical foot in gallons or bushels, as desired for its capacity.

RULE 3. When the vessel is a rhombus or rhomboid. Multiply its interior length in feet, its right-angular breadth in feet, and its depth in feet together, and the product by the capacity of a cubic foot in the special measure desired for its capacity.

RULE 4. When the vessel is a frustum of a cone—a round vessel larger at one end than the other, whose bases are planes. Multiply the interior diameter of the two ends together, in feet, add ⅓ the square of their difference in feet to the product, multiply the sum by the perpendicular depth of the vessel in feet, and that product by the capacity of a cylindrical foot in the unit of measure desired for its capacity.

RULE 5. When the vessel is a prismoid or the frustum of any regular pyramid. To the square root of the product of the areas of its ends in feet, add the areas of its ends in feet, multiply the sum by ⅓ its perpendicular depth in feet, and that product by the capacity of a cubic foot in gallons or bushels, as desired by its capacity.

If it is found more convenient to take the dimensions in inches, do so; proceed as directed for feet, divide the product by 1728, and multiply the quotient by the capacity of the respective foot as directed. Or, multiply the capacity in inches by the capacity of the respective inch in gallons or bushels; by the quotient obtained by dividing the capacity of the respective foot in gallons or bushels by 1728 for the contents.

RULE 6. When the vessel is a barrel, hogshead, pipe, etc. Multiply the difference in inches between the bung diameter and head diameter, (interior.) if the staves be

much curved.............................by .7
medium curved........................by .68
straighter than medium..............by .6
nearly straight..........................by .55

and add the product to the head diameter, taken in inches; then multiply the square of the sum by the length of the cask in inches, and divide the product by the capacity in cylindrical inches of a gallon or bushel as desired for the contents. Or, divide the contents in cylindrical inches, as above found, by 1728, and multiply the quotient by the capacity of a cylindrical foot in gallons or bushels as desired for its contents. Or, multiply the capacity in cylindrical inches by the capacity of a cylindrical inch, in gallons or bushels, as desired,—that is, by the quotient obtained by dividing the capacity of a cylindrical foot in gallons or bushels, by 1728, for the contents.

The capacity of

Cubic Foot=		Cylindrical Foot=	
7.4805 Winchester wine	gallons.	5.8752 Winchester wine	gallons.
7.8125 New York liquid	"	6.1359 New York liquid	"
6.1276 Ale	"	4.8126 Ale	"
6.2321 Imperial	"	4.8947 Imperial	"
.80356 Winchester	bushels.	.6311 Winchester	"
.78125 New York	"	.6136 New York	"
.78617 Connecticut	"	.61746 Connecticut	"
.779 Imperial	"	.51183 Imperial	"

MENSURATION OF LUMBER.

To find the contents of a board:

RULE.—Multiply the length in feet by the width in inches, and divide the product by 12; the quotient will be the contents in square feet.

EXAMPLE.—A board is 16 feet long and 10 inches wide; how many square feet does it contain?

$$16 \times 10 = 160 \div 12 = 13\ 4\text{-}12. \quad \textit{Ans.}$$

To find the contents of a plank, joist or stick of square timber.

RULE.—Multiply the product of the depth and width in inches by the length in feet, and divide the last product by 12; the quotient is the contents in feet.

EXAMPLE.—A joist is 16 feet long, 5 inches deep, and 2½ inches wide; how many feet does it contain?

$$5 \times 2.5 \times 16 \div 12 = 16\ 8\text{-}12. \quad \textit{Ans.}$$

To measure round timber.

RULE (in general practice.)—Multiply the length, in feet, by the square of ¼ the girt, in inches, taken about ⅓ the distance from the larger end, and divide the product by 144; the quotient is the contents in cubic feet.

EXAMPLE.—A stick of round timber is 40 feet in length, and girts 56 inches; how many cubic feet does it contain?

$$56 \div 4 = 14 \times 14 = 196 \times 40 \div 144 = 54.44 \text{ feet.} \quad \textit{Ans.}$$

OF CONDUITS OR PIPES.

To find the requisite thickness of a pipe, of any diameter, equal to the support of a given head of water.

RULE.—Multiply the head, in feet, by the diameter of the pipe, in inches, and divide the product by the reliable cohesive force, per square inch, of the material of which the pipe is composed; the quotient will be the required thickness.

NOTE. The reliable cohesion of a material is not above ⅓ its ultimate force, as given in the Table of Cohesive Forces. By experiment, it has been found that a cast iron pipe 15 inches in diameter and ¾ of an inch thick, will support a head of water of 600 feet; and that one of the same diameter made of oak, and 2 inches thick, will support a head of 180 feet—12000 lbs. per square inch for cast iron, 1200 for oak, 750 for lead, are counted safe estimates. The ultimate cohesion of an alloy, composed of *lead 8 parts, and zinc* 1 part, is 3000 pounds per square inch.

CONCERNING THE DISCHARGE OF PIPES, ETC.

Small pipes, whether vertical, horizontal, or inclined, under equal heads, discharge proportionally less water than large ones. That form of pipe, therefore, which presents the least perimeter to its area, other things being equal, will give the greatest discharge. A round pipe, consequently, will discharge more water in a given time than a pipe of any other form, of equal fluid.

The greater the length of a pipe discharging vertically, the greater the discharge. Because the friction of the particles against its sides, and consequent retardation, is more than overcome by the gravity of the fluid.

The greater the length of a pipe discharging horizontally, the less proportionally will be the discharge. The proportion compared with a less length is in the inverse ratio of the square root of the two lengths, nearly.

Other things being equal, rectilinear pipes give a greater discharge than curvilinear, and curvilinear greater than angular. The head, the diameters and the lengths being the same, the time occupied in passing an equal quantity of water through a straight pipe is 9, through one curved semi-circle 10, and through one having one right angle, otherwise straight, 14. All interior inequalities and roughness should be avoided.

It has been ascertained that a velocity of 60 feet a minute (1 foot a second) through a horizontal pipe, 4 inches in diameter and 100 feet in length, is produced by a head 2 1-7 inches, only 1-7 of an inch above the upper surface of the orifice; and that, to maintain an equal velocity through a pipe similarly situated, of equal length, having a diameter of ½ inch only, a head of 1 5-12 feet is required. To increase the velocity through the last mentioned pipe to 2 feet a second, requires a head 4 10-12 feet; to 3 feet, a head of 10 1-12; to 4 feet, a head of 17 10-12, etc.

From the foregoing, the following, it is believed, reliable rules, are deduced:

To find the velocity of water passing through a straight horizontal pipe of any length and diameter, the head, or height of the fluid above the centre of the orifice, being known.

RULE.—Multiply the head, in feet, by 2500, and divide the product by the length of the pipe in feet, multiplied by 13.9, divided by the interior diameter of the pipe in inches; the square root of the quotient will be the velocity in feet per second.

EXAMPLE.—The head is 6 feet, the length of the pipe 1340 feet, and its diameter 5 inches; required the velocity of the water passing through it.

$2500 \times 6 = 15000 \div \left(\frac{1340 \times 13.9}{5}\right) = \sqrt{4.03} — = 2$ feet per second. *Ans.*

To find the head necessary to produce a required velocity through a pipe of given length and diameter.

RULE.—Multiply the square of the required velocity, in feet, per second, by the length of the pipe multiplied by the quotient obtained by dividing 13.9 by the diameter of the pipe in inches, and divide the product thus obtained by 2500; the quotient will be the head in feet.

EXAMPLE.—The length of a pipe lying horizontal and straight is 1340 feet, and its diameter is 5 inches; what head is necessary to cause the water to flow through it at the rate of 2 feet a second?

$2^2 \times 1340 \times \frac{13.9}{5} \div 2500 = 6$ feet. *Ans.*

To find the quantity of water flowing through a pipe of any length and diameter.

RULE.—Multiply the velocity in feet per second by the area of the discharging orifice, in feet, and the product is the quantity in cubic feet discharged per second.

EXAMPLE.—The velocity is 2 feet a second, and the diameter of the pipe 5 inches; what quantity of water is discharged in each second of time?

$5 \div 12 + .4166$, and $.4166^2 \times .7854 \times 2 = .273$ cubic foot. *Ans.*

MISCELLANEOUS PROBLEMS.

To Ascertain the Cost of Hay.

RULE.—Multiply the number of pounds by half the price per ton, and remove the decimal point three places to the left.

EXAMPLE.—What is the cost of 824 lbs. of hay at $16 per ton?

$16 \div 2 = 8 \times 824 = 6.592$. *Ans.*—$6.59.2.

NOTE. The above rule applies to anything of which 2000 lbs. is a ton.

To Measure Grain.

RULE.—Level the grain; ascertain the space it occupies in cubic feet. Multiply the number of cubic feet by 8, and point off one place to the left.

NOTE. Exactness requires the addition to every 3 hundred bushels of 1 extra bushel.

The foregoing rule may be used for finding the number of gallons, by multiplying the number of bushels by 8.

RULE.—If the grain be corn in the car, divide the answer by 2 to find the number of bushels of shelled corn.

Rapid Rules for Measuring Land without Instruments.

The first thing to ascertain is the contents of any given plot in square yards; then the number of yards being given, find out the number of rods and acres.

The most ancient and simplest manner is a step. An ordinary sized man can train himself to cover 1 yard at a stride, on the average, with sufficient precision for ordinary purposes.

To make use of this means of measuring distances, it is essential to walk in a straight line. To do this, fix the eye on two objects in a line straight ahead, one comparatively near, the other remote, and in walking keep these objects constantly in line.

A Convenient Measure for Inches.

A man about 5 feet 10 inches high will span 9 inches from tip of thumb to tip of little finger; 6 inches from end of thumb to outer edge of hand. A man of any height will span about the same from end of right middle finger to end of left.

This rule is generally applicable except in cases of deformity.

For Grindstones.

Sometimes they are sold by weight, at other times by measure.

RULE.—If by weight, square the diameter, in inches, multiply by thickness, in inches, then by the decimal .06363; the product will be the weight of the stone in pounds.

If by measure in square feet or inches.

RULE.—Add the diameter to half the diameter, multiply the sum by *the same half*, multiply the product by the thickness, divide the last (if *feet is required*) product by 1728 for the answer.

For Squaring the Sills of a Frame, or Laying Out Two Right Angle Lines.

Measure 8 feet from the corner on one sill or line and on the other 6 feet, place a 10-foot pole across the hypothenuse and bring the sill or line at the points marked, so that the 10-foot pole will be the right length between the points mentioned.

To Find the Specific Gravity of a Body Heavier than Water.

RULE.—Weigh the body in water and out of water, and divide the weight out of water by the difference of the two weights.

EXAMPLE.—A piece of metal weighs 10 lbs. in atmosphere, and but 8¼ in water; required its specific gravity.

$$10-8.25=1.75, \text{ and } 10 \div 1.75=5.714. \quad \textit{Ans.}$$

To Find the Specific Gravity of a Body Lighter than Water.

RULE.—Weigh the body in air; then connect it with a piece of metal whose weight, both in and out of water, is known, and of sufficient weight that the two will sink in water; and find their combined weight in water; then divide the weight of the body in air by the weight of the two substances in air, less the sum of the difference of the weight of the metal in air and water and the combined weight of the two substances in water, and the quotient will be the specific gravity sought.

EXAMPLE.—The combined weight, in water, of a piece of wood and piece of metal is 4 lbs.; the wood weighs in atmosphere 10 lbs.; and the metal in atmosphere 12, and in water 11 lbs.; required the specific gravity of the wood.

$$10 \div \overline{10+12-12 \backsim 11+4}=.588. \quad \textit{Ans.}$$

To Find the Specific Gravity of a Fluid.

RULE.—Multiply the known specific gravity of a body by the difference of its weight in and out of the fluid, and divide the product by its weight out of the fluid; the quotient will be the specific gravity of the fluid in which the body is weighed.

EXAMPLE.—The specific gravity of a brass ball is 8.6; its weight in atmosphere is 8 oz., and in a certain fluid 7¼ oz., required the specific gravity of the fluid.

$$8-7.25=.75, \text{ and } 8.6 \times .75=6.45, \text{ and } 6.45 \div 8=.806. \quad \textit{Ans.}$$

To find the proportion of one to the other of two simples forming a compound or the extent to which a metal is debased, (the metal and the alloy used being known.)

EXAMPLE.—The specific gravity of gold is 19.258, and that of copper, 8.788; an article composed of the two metals has a specific gravity of 18; in what proportion are the metals mixed?

$$18 \backsim 19.258 \times 8.788 = 11.055$$
$$18 \backsim 8.788 \times 19.258 = 177.4, \text{ then}$$

$$\left.\begin{array}{l} \overline{11.055 + 177.4} : 11.055 :: 18 = 1.056 \text{ copper.} \\ \overline{11.055 + 177.4} : 177.4 :: 18 = 16.944 \text{ gold.} \end{array}\right\} \textit{Ans.}$$

Or, 18—1.056=16.944 gold. Copper to gold as 1 to 16.04+.

To Find the Lifting Power of a Balloon.

RULE.—Multiply the capacity of the balloon, in feet, by the difference of weight between a cubic foot of atmosphere and a cubic foot of the gas used to inflate the balloon, and the product is the weight the balloon will raise.

EXAMPLE.—A balloon, whose diameter is 24 feet, is inflated with hydrogen; what weight will it raise?

Specific gravity of air is 1, weight of a cubic foot 527.04 grains; specific gravity of hydrogen is .0689.
527.04 × .0689 = 36.31 grains = weight of 1 cubic foot of hydrogen.
527.04 — 36.31 = 490.73 grains = difference of weight of air and hydrogen.
$24^3 \times .5236 = 7238.24$ = capacity in cubic feet of balloon.
Then, 7238.26 × 490.73 = 3552021 grs. $= \frac{3552021}{7000} = 507\frac{4}{10}$ lbs. *Ans.*

To find the Diameter of a Balloon that shall be Equal to the Raising of a Given Weight.

The weight to be raised is 507 4-10 lbs.

$\overline{507.} \times 7000 \div 490.73 = 7238.24$, and $7238.24 \div .5236 = \sqrt[3]{13824} = 24$ feet. *Ans.*

To Find the Thickness of a Concave or Hollow Metallic Ball or Globe, that shall have a Given Buoyancy in a Given Liquid.

EXAMPLE.—A concave globe is to be made of brass, specific gravity 8.6, and its diameter is to be 12 inches; what must be its thickness that it may sink exactly to its centre in pure water?

Weight of a cubic inch of water .036169 lb.; of the brass .3112 lb.
Then, $12^3 \times .5236 \times .036169 \div 2 = 16.3625$ cubic inches of water to be displaced.
$16.3625 \div .3112 = 52.5787$ cubic inches of metal in the ball.
$12^2 \times 3.1416 = 452.39$ square inches of surface of the ball.
And, 52.5787 ÷ 452-39 = .1162 + = 1-9 inch, thick, full. *Ans.*

To cut a Square Sheet of Copper, Tin, etc., so as to form a Vessel of the Greatest Cubical Capacity the Sheet Admits of.

RULE.—From each corner of the sheet, at right angles to the side, cut 1-6 part of the length of the side, and turn up the sides till the corners meet.

Comparative Cohesive Force of Metals, Woods and other substances, Wrought Iron (medium quality) being the unit of comparison, or 1; the Cohesive Force of which is 60000 lbs. per inch, cross section.

Wrought Iron	1.00	Steel, fine	2.25
" " wire	1.71	Tin, cast block	.83
Copper, cast	.54	Zinc. "	.043
" wire	1.02	" sheet	.27
Gold, cast	.34	Brass, cast	.75
" wire	.51	Gun metal	.50
Iron, cast (average)	.56	Gold 5, copper 1	.83
Lead, "	.016	Silver 5, " 1	.80
" milled	.055	Brick	.05
Platinum, wire	.88	Slate	.20
Silver, cast	.66	Ash, white	.23
" wire	.68	" red	.30
Steel, soft	2.00	Beech	.19

irch	.25	Pine, pitch	.20
ox	.33	Sycamore	.22
edar	.19	Walnut	.30
hestnut, sweet	.17	Willow	.22
ypress	.10	Ivory	.27
lm	.22	Whalebone	.13
ocust	.34	Marble	.15
[ahogany, best	.36	Glass, plate	.16
[aple	.18	Hemp fibres, glued	1.53
'ak, Amer. white	.19		

The strength of white oak to cast iron, is as 2 to 9.
The stiffness " " " " " is as 1 to 13.

'o determine the weight, or force, in pounds, necessary to tear asunder a bar, rod, or piece of any of the above named substances, of any given cross section.

RULE.—Multiply the comparative cohesive force of the substance, as iven in the table, by the cohesive force per square inch, area of cross sec- ion (60000 lbs.) of wrought iron, which gives the cohesive force of 1 quare inch area of cross section of the substance whose power is sought to e ascertained, and the product of 1 square inch thus found, multiplied by rea of cross section, in inches, of the rod, piece, or bar itself, gives the ohesive force thereof.

lloys having a Tenacity Greater than the Sum of their Constituents.

wedish copper	6 pts.,	Malacca tin 1;	tenacity	per	square	inch,	64000	lbs.
'hili	" 6 "	" " "	"	"	"	"	60000	"
apan	" 5 "	Banca " "	"	"	"	"	57000	"
nglesea	" 6 "	Cornish " "	"	"	"	"	41000	"
'om. block-tin	4 "	lead 1, zinc "	"	"	"	"	13000	"
Ialacca tin	4 "	regulus of antimony 1;	"		"	"	12000	"
3lock-tin	3 "	lead 1 part;	tenacity	"	"	"	10000	"
3lock-tin	8 "	zinc 1 "	"	"	"	"	10200	"
'inc	1 "	lead 1 "	"	"	"	"	4500	"

lloys having a Density Greater than the Mean of their Constituents.

Gold with antimony, bismuth, cobalt, tin or zinc.
Silver with antimony, bismuth, lead, tin or zinc.
Copper with bismuth, palladium, tin or zinc.
Lead with antimony.
Platinum with molybdinum.
Palladium with bismuth.

lloys having a Density Less than the Mean of their Constituents.

Gold with copper, iron, iridium, lead, nickel or silver.
Silver with copper or lead.
Iron with antimony, bismuth or lead.
Tin with antimony, lead or palladium.
Nickel with arsenic.
Zinc with antimony.

RELATIVE POWER OF DIFFERENT METALS TO CONDUCT ELECTRICITY.

(The mass of each being equal.)

Copper	1000	Platinum	188
Gold	936	Iron	158
Silver	736	Tin	155
Zinc	285	Lead	83

Lime, palladium, platinum, rhodium, silex, may be melted by means of strong lenses, or hydro-oxygen blowpipe.

MELTING POINTS OF METAL AND WHEN OTHER BODIES CHANGE FORM.

SMELTING POINTS.	Deg. Fah.	BOILING POINTS.	Deg. Fah.
Cast iron, fully smelted	2754	Oil of Linseed,	600
Gold, fine	1983	Sweet Oil,	412
Silver, "	1850	Sulphuric Acid,	410
Copper "	2160	Sulphur,	390
Brass, common	1900	Phosphorus,	374
Zinc,	740	Oil of Turpentine,	315
Antimony,	790	Sea water, salt	217
Lead,	594	Water, distilled	212
Bismuth,	476	Alcohol, 90 per cent	174
Tin,	421	Ether, sulph	97
Solder, common	475	Benzine,	84
" plumbers	360	Naptha,	65
1 Tin, 1 Bismuth,	283	MISCELLANEOUS.	
3 Tin, 2 Lead, 5 Bismuth,	212	Iron, welding heat	2552
1 Tin, 1 Lead, 4 Bismuth,	201	Metals, Red, daylight	1077
Sulphur,	228	Common fire,	790
Phosphorus,	109	Iron, red, daylight,	884
Beeswax, white	155	" bright red in dark	752
" yellow	142	Human blood,	98
Tallow,	92	Cold greatest ever produced,	—90
Ice,	32	Vinous permentation,	—60 to 70
1 Snow, 1½ Salt,	0	Acetous fermentation begins,	—78
Mercury,	—39	Acetification ends	—88
Mercury boils	656	Phosphorus burns,	—43

RELATIVE POWER OF DIFFERENT BODIES TO RADIATE HEAT.

Water	100	Lead, bright	19
Copper	12	Mercury	20
Glass	90	Paper, white	100
Ice	85	Silver	12
India ink	88	Tin, blackened	100
Iron, polished	15	" clean	12
Lampblack	100	" scraped	16

NOTE. The power of a body to reflect heat is inverse to its power of radiation.

BOILING POINT OF LIQUIDS.

(Barometer at 30 in.)

Acid, nitric	253°	Oils, essential, avg	318°
" sulphuric	600°	" turpentine	316°
Alcohol, anhyd	168.5°	" linseed	640°
" 90%	174°	Phosphorus	554°
Ether, sulph	97°	Sulphur	560°
Mercury	656°	Water	212°

NOTE. Barometer at 31 inches, water boils at 213°.57; at 29, it boils at 210°.38; at 28, it boils at 208°.69; at 27, it boils at 206°.85, and in vacuo it oils at 88°. No liquid, under pressure of the atmosphere alone, can be ated above its boiling point. At that point the steam emitted sustains weight of the atmosphere.

FREEZING POINT OF LIQUIDS.

	Deg.		Deg.
Acid, nitric	—55	Oil, linseed, avg	—11
" sulphuric	1	Proof spirits	—7
Ether	—47	Spirits turpentine	16
Mercury	—39	Vinegar	28
Milk	30	Water	32
Oil, cinnamon	30	Wine, strong	20
" fennel	14	Rapeseed oil	25
" olive	36		

NOTE.—Water expands in freezing .11, or 1-9 its bulk.

EXPANSION OF FLUIDS BY BEING HEATED FROM 32° TO 212°, F.

Atmospheric air, $\frac{1}{480}$ per each degree	= .375
Gases, all kinds, $\frac{1}{480}$ " " "	
Mercury, exposed	.018
Muriatic acid, (sp. gr. 1.137.)	.060
Nitric acid, (sp. gr. 1.40.)	.110
Sulphuric acid, (sp. gr. 1.85.)	.060
" ether,—to its boiling point	.070
Alcohol, (90 per cent.,) " "	.110
Oils, fixed	.080
" turpentine	.070
Water	.046

RELATIVE POWER OF SUBSTANCES TO CONDUCT HEAT.

Gold	1000	Zinc	363
Silver	973	Tin	304
Copper	898	Lead	180
Platinum	981	Porcelain	012
Iron	374	Fire brick	011

NOTE. Different woods have a conducting power in ratio to each other, as are their respective specific gravities, the more dense having the greater.

NEW STANDARD TIME.

To change to the New Standard Time, apply a plus or minus correction, which is to be found by subtracting the adopted "division" or "standard" longitude of the place from its Greenwich longitude reduced to time.

For example: the "division" longitude adopted for Boston is 75°, or 5 hours; which subtracted from its actual longitude of 71° 4', or 4h. 44m., gives a correction of (—3° 56',) 16 minutes to be subtracted from the printed values for Boston.

Again: the "division" longitude of Omaha is 6 hours, which subtracted from Omaha's longitude of 6h. 24m., leaves a correction of 24 minutes to be added, in order to change to Omaha's standard.

CORRECTION FOR THE FOLLOWING CITIES.

EASTERN STANDARD.—75° Lon.	Minutes.	CENTRAL STANDARD.—90° Lon.	Minutes.
Bangor, Me	— 25	Cleveland, Ohio	— 33
Augusta, Me	— 21	Columbus, Ohio	— 28
Portland, Me	— 19	Detroit, Mich	— 28
Boston, Mass	— 16	Toledo, Ohio	— 26
Newport, R. I	— 15	Dayton, Ohio	— 23
Providence, R. I	— 14	Cincinnati, Ohio	— 22
Concord, N. H	— 14	Louisville, Ky	— 18
New London, Ct	— 11	Indianapolis, Ind	— 16
Springfield, Mass	— 10	Chicago, Ill	— 10
Montpelier, Vt	— 10	Milwaukee, Wis	— 8
Hartford, Ct	— 9	Springfield, Ill	— 2
Montreal, Que	— 6	Memphis, Tenn	— 0
Albany, N. Y	— 5	New Orleans, La	— 0
New York, N. Y	— 4	St. Louis, Mo	+ 1
Utica, N. Y	+ 1	Rock Island, Ill	+ 3
Philadelphia, Pa	+ 1	Dubuque, Iowa	+ 3
Syracuse, N. Y	+ 5	Burlington, Iowa	+ 5
Baltimore, Md	+ 6	St. Paul, Minn	+ 12
Washington, D. C	+ 8	Des Moines, Iowa	+ 14
Rochester, N. Y	+ 11	Kansas City, Mo	+ 18
Buffalo, N. Y	+ 16	Galveston, Tex	+ 19
Pittsburg, Pa	+ 20	Omaha, Neb	+ 24
MOUNTAIN STANDARD.—105° Lon.		PACIFIC STANDARD.—120° Lon.	
Denver, Col	0	Sacramento, Cal	+ 6
Salt Lake City, Utah	+ 28	San Francisco, Cal	+ 10

HYDROSTATICS.

All fluids, at rest, press equally in every direction. The pressure exerted by them, therefore, can never be so little as their weight, and may, under circumstances, be to almost any conceivable extent greater. The downward pressure exerted by a fluid is its weight, and its weight is as the quantity; but the lateral pressure exerted is in a measure independent of quantity, being dependent upon depth, or vertical height.

Any given area, in any given section of a containing vessel, is pressed equal to the weight of a column of the fluid whose base is equal to the area pressed, and whose height is equal to the distance of the centre of gravity of that area, below the surface of the fluid; this is the case whether the sustaining surface be horizontal, or vertical, or oblique.

The bottom of a containing vessel, therefore, whatever be its shape, sustains a pressure equal to the weight of the superincumbent fluid, or equal to the weight of a column of the fluid whose base is equal to the area of the bottom, and height equal to the distance from the bottom to the surface—equal to the area of the bottom, multiplied by the depth of the liquid multiplied by its weight, in like terms of measurement.

And each side of the containing vessel, whatever number of sides there be, sustains a pressure equal to the area of that side multiplied by half the

depth of the liquid, multiplied by its weight, in the same terms of measurement.

Thus, a rectangular vessel, whose sides and bottom are equal, and each two feet square, has a capacity of 8 cubic feet; it will hold, consequently, 8 cubic feet of fresh water, one cubic foot of which weighs $62\frac{1}{2}$ lbs. It will hold, therefore, $62\frac{1}{2}\times 8=500$ lbs. of water. Now, if we suppose this vessel filled with water, we have, according to the foregoing, a pressure on the bottom of $2\times 2\times 2\times 62.5=500$ lbs.: a pressure exactly equal to the weight of all the fluid. And we have, upon each of the four sides, a pressure of $2\times 2\times 1\times 62.5=250$ lbs.; a lateral pressure, therefore, equal to $250\times 4=1000$ lbs., equal to twice the pressure on the bottom, and showing the entire pressure exerted to be 300 per cent. greater than the weight of the water employed.

Again: if we suppose the above vessel contracted, laterally, to the extent that its sides are but 3 inches, or $\frac{1}{4}$ of a foot apart, throughout, and that its length is so extended that it still holds the 8 cubic feet of water, then we have, upon the bottom, whose area is only 9 square inches, a pressure of $.25\times .25\times 128\times 62.5=500$ lbs. as before; and upon each side we have a pressure of $.25\times 128\times \frac{128}{2}\times 62.5=128000$ lbs.; making in all a pressure of $128000\times 4+500$,—the enormous pressure of 512500lbs., and that too, exerted by 8 cubic feet or 500 lbs. of water. It is easy to see that the same principles hold good under any extent of lateral area.

EXAMPLE:—A sluice or flood-gate is 3 feet by $2\frac{1}{2}$, and its centre is 12 feet below the surface of the water; what pressure does the water exert upon it?

$$3\times 2.5\times 12\times 62.5=5625 \text{ lbs.} \quad \textit{Ans.}$$

EXAMPLE.—A dam, that presents a perpendicular resistance to a stream, is 40 feet long and 15 feet high; the water is level with its top; what pressure does the dam sustain, supposing the water at rest, and what is the mean pressure against it per square foot?

$40\times 15\times \frac{15}{2}\times 62.5=281250$ lbs., pressure against the dam; and

$281250\div\overline{40\times 15}=468\frac{3}{4}$ lbs., mean pressure per sq. foot. *Ans.*

EXAMPLE.—The same stream, the same length of dam, and the same vertical height as the preceding, and the dam sloping into the stream against the current, 30 feet from its base; required the pressure against the dam, and the average pressure per square foot.

$40\times 15\times 7.5\times 62.5=281250$ lbs., pressure as before.

$\sqrt{15^2+30^2}=33.541$ feet, slant height of dam; and

$281250\div\overline{40\times 33.541}=209.63$ lbs. av'g pres. per sq. foot. *Ans.*

For calculating the horse power of a given quantity of water in a given time, 7,000,000 gallons of water passing through the turbine in 60 hours.

RULE.—Multiply the fall in feet by .3682; the product is the horse power net. This is unit. If there is more or less water, or more or less time, the horse power developed will be more or less in direct proportion.—[From testimony of J. B. Francis, C. E.

Another rule: 8.8 cubic feet of water per second falling 1 foot, is equal to one horse power.—[From testimony of C. Hershell, C. E.

HYDRAULICS.

The established law for the velocity of all bodies falling from rest is given under *Gravitation*, viz., that $\sqrt{\text{height}\times 64.66}$, or $\sqrt{\text{height}}\times 8.04=$

velocity per second, or velocity in one second of time, the velocity and height both being in the same denomination of measure. And from what has been said concerning pressure, under Hydrostatics, it is evident that the same law will cause water or other fluid to flow through an opening in the side of the reservoir, or dam, with the same velocity that a body would attain falling perpendicularly through a space equal to that between the surface of the water and the centre of the opening alluded to; and that, consequently, theoretically, the quantity thus discharged, in any given time, will be equal to the product of the velocity and area of the opening, multiplied by that time.

The theoretical law, however, last adduced, under ordinary circumstances, does not apply. And the quantity discharged, owing to the contraction of the fluid vein, caused by the friction of the particles against the sides of the opening, falls short of that theoretically due. The only instance known in which the full force of the law may be obtained, is where the discharge is made to issue through a straight tube whose form is the frustum of a cone, its length being half the diameter of the aperture, and the diameter of the receiving end to that of the discharging end as 5 to 8; when a fluid is allowed to pass through such an opening, no contraction of the vein takes place.

From various carefully conducted experiments by M. Morin, Eytelwein, Bossut, and others, the following practical rules for ascertaining the quantity discharged through different openings, and under different heads, are derived:—

1. When the issue is through a circular opening, its upper vertical point as high as the surface of the fluid, estimate the height or head from the centre of the opening to the surface of the fluid, and use 5.4, instead of 8.04, as the coefficient of quantity.

2. When the opening is circular, and under a head equal to its diameter, estimate the head as in the preceding, and use 8 as the coefficient.

3. When the issue is through a rectangular orifice, two or more feet beneath the surface, estimate the head from the centre of the orifice to the surface of the water, and use 5.1 as the coefficient.

4. When the discharge is from a rectangular opening, extending as high as the surface of the fluid, estimate the head from the bottom of the opening to the surface of the water, and use 3.4 as the coefficient. This rule applies to water flowing over a dam, or from a notch or slit cut in its side, etc.

It may be proper to add, that if the orifice is small and under considerable head, the quantity discharged, relatively, will be slightly, less than would be discharged if the opening were nearer the surface.

From the foregoing we obtain the following

General Rule.

Multiply the square root of the height, or head (as estimated in the foregoing), in feet, by the coefficient of quantity given as pertaining thereto, and the quotient will be the coefficient velocity in feet per second of the discharge; which, multiplied by the area of the opening in feet, gives the quantity in cubic feet discharged in a single second, or in each second of time.

Example.—A rectangular opening in the side of a dam is 6 feet long and 8 inches deep, and the distance from the centre of the opening to the surface of the water is 4 feet; required the quantity of water discharged in each second of time.

$\sqrt{4}=2\times5.1\times6\times\frac{2}{3}=40.8$ cubic feet. Ans.

EXAMPLE.—A dam is 60 feet long, and the water flows over its entire ength 6 inches, or ½ foot deep; what quantity flows over per second?

$\sqrt{.50}$*=.7071×3.4×60×.5=72⅛ cubic feet. *Ans.*

THE HYDRAULIC OR HYDROSTATIC PRESS.

This is a machine by which a small force may be made to exert a great pressure. Its construction may be understood by stating that it has a large, strong cylinder. fitted with a plunger securely packed where it works into the cylinder. At the outer end, attached to the plunger, is a heavy plate working between the tie rods, which secures the top to the bottom of the press, upon which rests the large cylinder. At the bottom of this cylinder is a small pipe, which conveys the fluid from the small force pump which produces the power. There is also a large faucet or valve in the large cylinder to relieve it quickly when necessary.

The pump may be operated by hand lever or power. A safety valve may be attached to relieve excessive pressure; also a gauge to note the pressure. The compression obtained by the press, is the proportion the pump and pipe bears to the area of the cylinder, with the power exerted.

The weight of a man's hand might thus be made to lift many thousand tons, the only limit being the strength of the machine.

THE HYDRAULIC RAM.

The ram can be applied to convey water a distance of from 100 to 200 rods, and to elevations of from 100 to 200 feet.

A fall of 10 feet from the spring or brook to the ram is sufficient to force the water to any elevation not over 150 feet above the ram, and in distance not over 150 rods from it.

Although the same fall will raise water to a much greater elevation, and force it to a greater distance, yet the quantity will diminish as the height and distance are increased.

When a sufficient quantity of water is raised by an adequate fall, the fall should not be increased, as by so doing the strain upon the ram is unnecessarily increased, and its durability lessened.

The proportion which the height to which the water is raised, and the quantity raised, bear to the fall and to the volume of the spring or stream, is about five times the height of the fall, and 1-7 of the volume of the stream forced a distance of 50 rods—allowing for the friction in both the supply and discharging pipes.

Thus, if the ram be placed under a fall of 5 feet, for every 7 gallons drawn from the spring, 1 gallon may be raised 25 feet, or ½ a gallon 50 feet, and forced a distance of 50 rods. If the fall be 10 feet, it will raise one gallon 50 feet, or ½ a gallon 100 feet, for every 7 gallons discharged by the stream. If the fall be 10 feet, and the volume of the stream be doubled, it will raise 1 gallon 100 feet, and so on in the same ratio.

FRACTIONS—DECIMALS.

A fraction is one or more parts of a unit, and is expressed by fractional characters, thus, ½, ¼, ¾; or by decimals, thus, .5, .25, .75.

When expressed by fractional characters, the upper figure is called the *numerator*, because it numbers or gives value to the fraction, by showing how many parts of the whole number into which the unit is divided are taken; and the lower figure is called the *denominator*, because it names the number of parts into which the unit is divided. Thus, ⅜ means that the unit is divided into 8 parts, and that 3 out of the 8 are taken, etc.

When *expressed by* a decimal, the decimal number shows that so *many parts of the unit* are taken, the unit itself being impliedly divided

into as many parts as will correspond with the decimal number, and still retain its ratio to it. Thus, .5 means $\frac{5}{10}$, .25 means $\frac{25}{100}$, .125 means $\frac{125}{1000}$, etc., etc.

To reduce fractions to decimals.

Divide the numerator by the denominator, adding ciphers as required.

EXAMPLE.—What are the decimals of $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$?

SOLUTION.—$10 \div 2 = .5$, $300 \div 4 = .75$, $7000 \div 8 = .875$. *Ans.*

To add decimals.

Add as in common addition, setting the whole numbers or integers directly under each other from the decimal point to the left, and the decimals from the decimal point to the right, as in the following example:—

```
12.75
24.027
14.5
16.1278
-------
67.4048
```

To subtract decimals.

Set the whole numbers and decimals under each other, as directed above, and proceed as in common subtraction, as in the following example:

```
75.15
28.875
------
46.275
```

To multiply decimals.

Set the figures and multiply as in common multiplication, and point off in the product as many decimals as there are decimal places in the multiplier and multiplicand, as in the following example:

```
   23.25
   22.15
   -----
   11625
   2325
  4650
 4650
--------
514.9875
```

To divide decimals.

Proceed as in common division, and point off to the right in the quotient as many decimals as the decimal places in the dividend exceed the decimal places in the divisor, as in the following example:

```
2.48)129.952(52.4
     124 0
     -----
       5 95
       4 96
       ----
         992
         992
         ---
```

CONTENTS.

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THE

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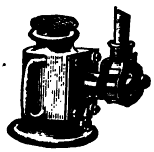

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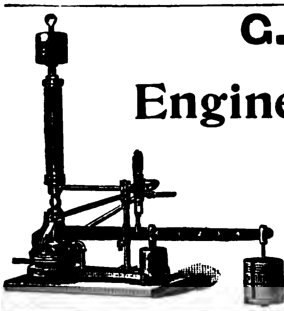

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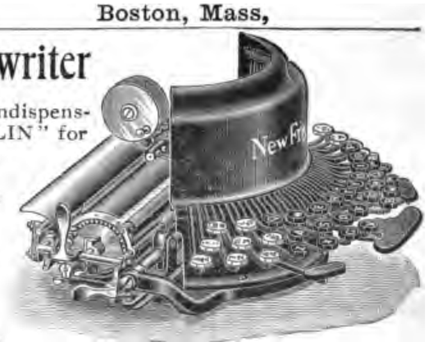

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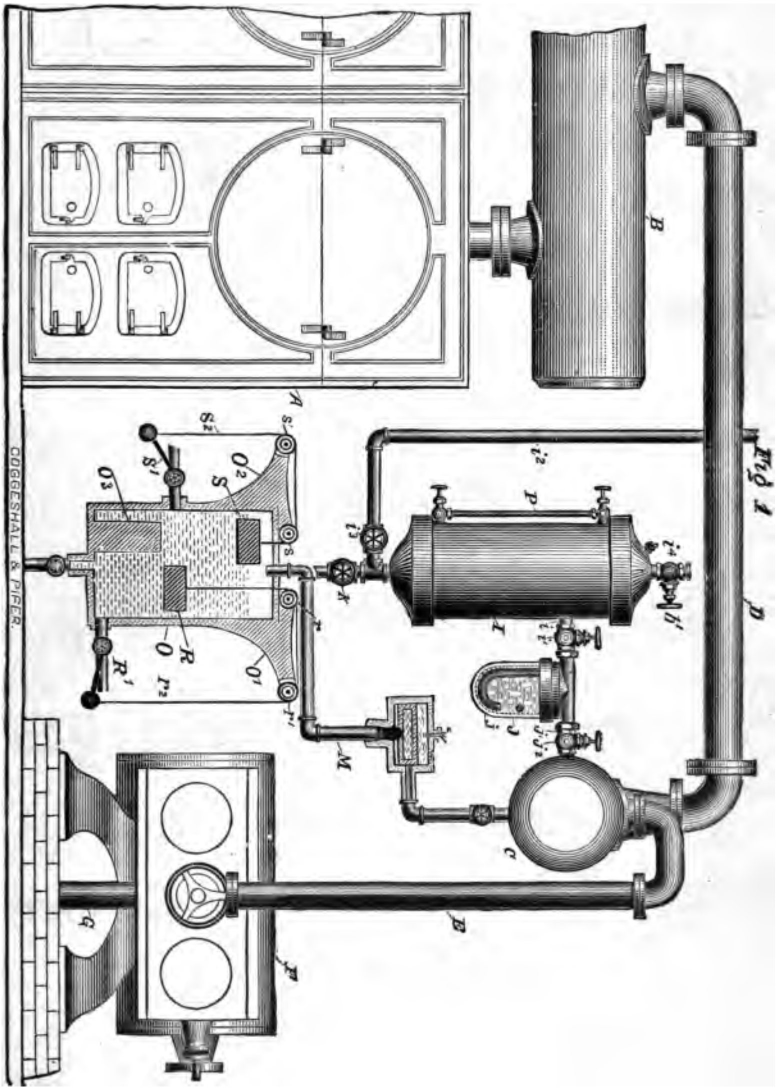

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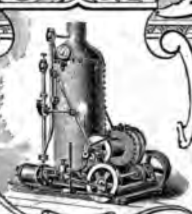

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